THE NICKEL BULLETIN

A MONTHLY SUMMARY OF CURRENT INFORMATION

SEPTEMBER/OCTOBER, 1958

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THE MOND NICKEL COMPANY LTD • THAMES HOUSE, MILLBANK, LONDON, S.W.1
Telephone:- Victoria 3888

Alloy	Specification	Composition, *per cent.*								
		Ni	Cr	Mo	Fe	Si	Mn	C	Cu	Other Elements
Nickel		Bal.	—	—	1·0 max.	1·0-2·0	0·5-1·5	0·3 max.	0·30 max.	Pb Nil. S 0·05 max. others not more than 0·5 including 0·08-0·12 Mg.
Nickel-chromium-iron alloy—Inconel[1] type		Bal.	12·0-15·0	—	5·0-10·0	0·5-2·0	0·5-1·0	0·3 max.	0·25 max.	Pb Nil. S 0·05 max. others not more than 0·5 including 0·1 Ca.
Monel[1] Normal Grade	B.S./S.T.A.7 NC.2	63·0-68·0	—	—	3·0 max.	0·5-1·2	0·5-1·5	0·3 max.	Bal.	Pb Nil. S 0·06 max. others not more than 0·5 including 0·08-0·12 Mg.
with 2·75% silicon	B.S./S.T.A.7 NC.3A.	63·0-68·0	—	—	3·0 max.	2·5-3·0	0·5-1·5	0·12 max.	Bal.	Pb Nil. S 0·05 others not more than 0·5 including 0·08-0·12 Mg.
with 3·75% silicon	B.S./S.T.A.7 NC.3B.	63·0-68·0	—	—	3·0 max.	3·5-4·0	0·5-1·5	0·12 max.	Bal.	Pb Nil. S 0·05 others not more than 0·5 including 0·08-0·12 Mg.
with 3·0% aluminium		63·0-68·0	—	—	2·0 max.	0·5	2·0	0·12 max.	Bal.	Pb Nil. Al 2·75-3·25 others not more than 1·0
Hastelloy[2] A		53·0	—	22·0	22·0	1·0	2·0	—	—	—
B		60·0	—	32·0	6·0	1·0	1·0	—	—	—
C		51·0	17·0	19·0	6·0	1·0	1·0	—	—	W 5·0
D		85·0	—	—	—	10·0	1·0	—	3·0	Al 1·0

[1] Trade Marks of Messrs. Henry Wiggin & Co. Ltd.

[2] Trade Marks of Haynes Stellite Co.

Mechanical Properties					Condition	Typical Application
Proof Stress[3] 0·1 per cent. tons/sq. in.	Yield Point tons/sq. in.	Max. Strength tons/sq. in.	Elong. per cent. in 2 in.	Hardness B.H.N.		
7·5	9-13	24-28	10-30	100-125	Sand cast	Miscellaneous castings for chemical and food-handling equipment, valves, mixer blades, pumps, etc.
12	15-20	28-33	5-15	150-200	Sand cast	Particularly suitable for dairy and food equipment. Under certain conditions the corrosion-resistance of cast Inconel is not quite so good as the wrought product but an improvement can be obtained by increasing the chromium content to 30 per cent.
10	11-15	23-33	16-40	100-150	Sand cast	Steam Valve trim for marine and industrial purposes. Cast Monel containing not more than 1·2 per cent. Si is non-ageing at steam temperatures up to 800°F. and is therefore suitable for valve bodies and unsupported valve lids, etc. Excellent resistance to softened boiler feed waters. Cast Monel containing 3·75 per cent. Si should be employed where maximum gall resistance is required. Also suitable for valves and valve seats in hydraulic, chemical and oil plant; Pump impellers and sleeves; Chemical and food equipment; marine fittings; pickling equipment.
15	18-23	33-40	8-15	180-230	Sand cast	
—	40-45	40-45	Nil.	230-260	Sand cast	
25	30-35	45-55	15-30	200-350	Sand cast	
—	19-20	30-34	8-12	150-200	Sand cast	Castings for chemical plant, etc. Withstands hydrochloric acid in all concentrations up to 70 per cent.
—	24-25	34-36	6-9	190-230	Sand cast	Suitable for equipment handling boiling hydrochloric acid and wet hydrochloric acid gas. Resists boiling sulphuric acid up to concentrations of 60 per cent.
—	20-21	32-35	10-15	175-215	Sand cast	Effectively withstands nitric acid, free chlorine, aqueous solutions containing chlorine or hypochlorites, etc.
—	16-18	16-18	Nil.	360	Sand cast	Resistant to all concentrations of sulphuric acid up to boiling point, acetic acid, formic acid and phosphoric acid.

[3] Figures for proof stress are approximate and should be used as a guide only.

ABSTRACTS OF CURRENT PUBLISHED INFORMATION ON NICKEL AND ITS ALLOYS

GENERAL

New Foundry for Production of Precision Castings

'Gateway to the Future. Samuel Osborn's Facilities for Precision Casting.'

Foundry Trade Jnl., 1958, vol. 105, July 10, pp. 33–52; July 17, pp. 77–9.

The Holbrook Steel Works of Samuel Osborn and Company, Ltd., which were recently opened, were built with the aim of bringing together all the specialized facilities necessary for the production of small high-quality precision castings by the shell-moulding, Osborn/Shaw and CO_2 processes. The operations in the new foundry are therefore entirely divorced from the more conventional foundry techniques used in the company's other foundry in Sheffield. In layout, care has been taken not only to provide for the peculiar needs of all three precision-casting techniques, but also to integrate them with the common facilities of melting shop, fettling shop, heat-treatment, process control, etc.

This article gives a description of the whole plant, in sections relating to flow processes; machinery and plant; moulding; core-making and casting; fettling; heat-treatment; production control; selection of processes for specific applications; future development.

An interesting feature is a detailed illustrated survey of actual case histories of castings produced at the foundry. Each of these fourteen case histories, which are intended 'to illustrate more than any other form of comment something of both the manufacturing procedure and the wide scope of the works', is supplemented by annotated photographs and diagrams of patterns, moulds or castings. Each history comprises a chart listing data relevant to the casting, ranging from the composition of the material and its heat-treatment to the moulds used and the casting temperature.

The majority of the components discussed were cast in chromium-nickel stainless steel (mainly of the 18–8 type): they cover such widely varying applications as 'mushrooms' for the textile industry, valves, access doors for aircraft, elbows for dairy equipment, bung bushes for brewery casks, and gearboxes.

Measurement of Thickness: Review and Bibliography

U.S. DEPARTMENT OF COMMERCE, NAT. BUR. STANDARDS: 'The Measurement of Thickness.'

N.B.S. Circular 585, Jan. 20, 1958; 79 pp.

The monograph has been prepared to bring together all available information on methods employed in measurement of thickness, and to review problems which are encountered in making such measurements. The methods described are dealt with in seven groups, classified according to the physical operating principle involved. The scope of the information contained is indicated below.

Mechanical Methods: (Weight/dimension relationships, acoustics, vibration, displacement with various conversions)

Chemical: (Stripping, spectrochemical analysis)

Electrical: (Dielectric breakdown, resistance, electrochemical, capacitance, thermoelectricity)

Magnetic: (Attractive force, reluctance, saturation, inductance, eddy currents)

Optical: (Microscopy, interferometry, diffraction, shadow)

X-ray : (Absorption, diffraction, backscatter, spectrometry)

Radioactive Radiation: (Absorption, backscatter, tracers).

The range of application of the respective methods, the degree of accuracy obtainable, and the advantages and limitations of the various procedures are discussed.

A *bibliography*, comprising references to 220 items of technical literature and to 10 patents is appended, and a list of U.S. manufacturers producing thickness-measuring instruments is given. The review is illustrated by some 150 drawings and photographs of typical instruments.

Calibration and Testing of Thermocouples

W. F. ROESER and S. T. LONBERGER: 'Methods of Testing Thermocouples and Thermocouple Materials.'

Nat. Bur. Standards, Circular 590, Feb. 6, 1958; 21 pp.

The authors' aim is to give a detailed description of the more important methods currently used to test and calibrate thermocouples, and, against this background, to draw attention to the factors which must be taken into account if the high degree of accuracy required is to be achieved. The methods discussed are illustrated mainly by reference to their use in calibrating platinum/platinum-rhodium, 'Chromel'/'Alumel', iron/'Constantan' and copper/'Constantan' thermocouples.

Calibration of thermocouples may be effected in two ways: (1) by determining the e.m.f. at a number of fixed points on the International Temperature Scale, or (2) by comparison with other thermocouples, the values for which have been established. In introducing discussion of the two methods, the

authors emphasize the importance of taking into account the thermoelectric inhomogeneity of thermocouple wire: reference is made to the stabilizing heat-treatment which is applied to the wire prior to calibration. Recommendations are made with regard to potentiometers suitable for use in calibration of thermocouples.

The first method of calibration (by measurement of the e.m.f. at pre-determined temperatures, e.g., the boiling point of sulphur, the freezing point of zinc) is considered in relation to procedure and apparatus used to establish values at the freezing points and melting points of metals. In the section concerned with the second method (calibration by comparison with working standards) the description of technique used for the precious- and base-metal thermocouples is linked with notes on the reproducibility achieved and the temperature ranges for which the respective couples are suitable.

The equations and curves used to interpolate the remaining temperature/e.m.f. values from those previously determined are exemplified for each of the four types of thermocouple considered in the paper: reference is made also to the corrections necessary to compensate for variations in temperature at the cold junction during calibration.

The penultimate section of the Circular covers methods by which materials are selected to yield a specified e.m.f. at one or more temperatures (e.g., comparison with a platinum standard), and the final section summarizes the accuracies obtainable with the methods of calibration previously reviewed.

A selective *bibliography* is included.

High-Temperature Testing of Metals

See abstract on p. 269.

Factors Affecting Stress-Rupture of Threaded Test Specimens

See abstract on p. 269.

High-Temperature Fatigue-Testing Machine

See abstract on p. 270.

NICKEL

Wet Carbonyl Process for Extraction of Nickel

R. M. LEWIS, J. W. COOKSTON, L. W. COFFER and F. M. STEPHENS: 'Iron and Nickel by Carbonyl Treatment.'

Jnl. of Metals, 1958, vol. 10, June, pp. 419-24.

The paper gives a detailed report of experimental laboratory-scale work which indicates the possibility of using a wet carbonyl process for treatment of lateritic low-grade nickel-containing ores such as those found in Cuba. Following discussion of the considerations which render attractive a technique involving extraction viâ the carbonyl, the authors describe results of a study of the thermodynamics of the reactions involving nickel and carbon monoxide and iron and carbon monoxide, carried out to obtain fundamental information essential to development of the extraction process.

A range of typical lateritic ores of various grades was subjected to treatments in which the influence of all essential variables was investigated. The factors studied included the effect of temperature and time of treatment in the hydrogen reduction of the ore, the influence of the composition of the ore on its reaction to treatment, the nature of the beneficial influence of ammonia additions to the carbon monoxide, the effects of variation in temperature and pressure on formation of the respective carbonyls, and the conditions necessary for optimum separation of the two gases. Some preliminary work on decomposition of the carbonyls is also reported.

Bench-scale tests indicated the possibility of integrating the necessary operations into a system which would permit transfer of all the solids, liquids and gases involved, without exposing them to the atmosphere. The sequence involved was (1) reduction of the ore by hydrogen treatment, (2) cooling of the reduced ore, (3) ammonia treatment of the reduced ore, (4) mixing of the reduced ore with iron carbonyl to form a slurry, (5) treatment of the slurry with carbon monoxide under pressure, (6) filtration of the treated slurry, (7) removal of the carbonyls from the filter cake, (8) separation of nickel carbonyl from iron carbonyl, (9) decomposition of nickel carbonyl, and (10) purification of iron carbonyl. Line drawings in the report show the equipment required in the various stages of the process. It is considered that the successful results obtained in operation of the integrated unit proved that the individual steps could be combined to give a process which would be technically feasible, and capable of giving high recoveries of iron and nickel from lateritic ores.

Resistance of Nickel to Corrosion by Caustic Alkalies

See abstract on p. 272.

Direct Rolling of Nickel Powder

D. K. WORN: 'The Continuous Production of Strip from Metal Powder by the Direct-Rolling Process.'

Sheet Metal Industries, 1958, vol. 35, Aug., pp. 615-19.

Full version of paper, the scope of which was indicated (from an abridgement) in *Nickel Bulletin*, 1958, vol. 31, No. 6, p. 173.

Nickel Catalyst in Production of Hydrogen for Fat Hardening

P. G. HERCULES: 'Hydrogen Plant for Stork Works.'

Chemical Age, 1958, vol. 80, July 5, p. 19.

This short article describes outstanding features of the large power-gas hydrogen plant incorporated in the fat-hardening unit at the Stork Margarine Works of Van den Bergh and Jurgens, Ltd., recently put into operation at Purfleet, Essex. This plant

produces highly pure hydrogen from propane, using the Hercules re-forming furnace.

Operation is in four main stages: (*a*) re-forming in catalyst-filled stainless-steel tubes enclosed in the furnace, (*b*) CO conversion and CO_2 removal, (*c*) CO conversion to CH_4, and (*d*) compression, drying and storage. The final gas is guaranteed to contain not more than 0·1 per cent. carbon dioxide, 10 p.p.m. carbon monoxide and 0·5 per cent. methane. In operation these impurities have been found to be present at much lower concentrations.

The catalyst used in the re-forming process is nickel.

Nickel-Cadmium Batteries in Missile Service

D. LINDEN and A. F. DANIEL: 'New Batteries for the Space Age.'

Electronics, 1958, vol. 31, July 18, pp. 59–65.

Electrochemical batteries offer many advantages in providing auxiliary power for missiles, but for such service design must be considerably modified from the conventional types, to satisfy many requirements which are not encountered in the more standard battery-operated forms of equipment. The features essential are briefly surveyed in the introductory section of this article, which comprises a review of the types of battery available, their advantages for such service, and the limitations of each type.

Although no entirely ideal battery has at present been developed, there are commercially available three types which come into consideration for high-rate applications: re-chargeable nickel-cadmium, reserve-type zinc/silver-oxide, and thermal batteries. A fourth type, gas-activated batteries, although not yet developed to the stage permitting practical use, offers promise.

All these types are illustrated, and are critically discussed: their respective properties are summarized in a table showing the characteristics of the individual batteries, and the names of some of the manufacturers in the U.S.A. Full particulars are given for the following types: dry cells, lead-acid, nickel-cadmium, zinc/silver oxide, thermal-cell, chlorine-depolarized, ammonia-vapour-activated. In discussion of the sintered-plate nickel-cadmium battery, attention is directed to the high degree of reliability attained, the long service life and the possibility of frequent re-charging, continuous floating, or trickle-charging, for maintenance in a condition constantly ready for operation. The robustness of nickel-cadmium batteries is a further major advantage: they can be operated under conditions of shock, acceleration and pressure, and retain some 50 per cent. of capacity after storage for a year at normal temperatures. For operation below about 30°F. (−1°C.) such batteries must be heated to ensure satisfactory performance.

From a capacity standpoint the zinc/silver oxide battery is attractive: it is stated to be coming increasingly into use, due to the importance of small size and light weight in missile applications. The low-temperature performance of these batteries is, however, unsatisfactory, and, in general, it is considered that extensive manufacturing and field experience will be required before their reliability can be assured. The thermal-cell models are useful in cases where the call is for a reserve battery having indefinite shelf life and the ability to develop full voltage rapidly, irrespective of ambient temperature. The principal attraction of gas-activated batteries is the simplicity of activation: the chlorine-depolarized type is notable for its high energy output per unit weight and volume. Zinc-chlorine batteries have, however, poor inactivated shelf life and do not give reliable performance after 6–8 months' storage at normal temperature, a disadvantage which has limited their use in the field. The most important advantage of the ammonia-vapour-activated type (ava) is likely to be in low-temperature applications.

Certain advantages known to be characteristic of dry cells and of conventional lead-acid batteries have not been sufficiently important to outweigh their disadvantages for use as auxiliary power sources in missiles.

Spectrophotometric Determination of Nickel

L. D. BRAKE, W. M. McNABB and J. F. HAZEL: 'A Spectrophotometric Method for the Determination of Nickel.'

Analytica Chimica Acta, 1958, vol. 19, July, pp. 39–42.

It has been found that the stable coloured complex formed in a reaction of versene with nickel can be used as a spectrophotometric method for the determination of that metal. The spectra for the nickel-versene complex show three absorption bands, one in the ultraviolet, one in the visible and one in the near-infrared region. The last-named band, which shows a maximum at 1,000μ, was chosen because many of the metal complexes of versene do not absorb at that wave length. It was thus found possible to determine nickel in the presence of the following ions: aluminium (III), beryllium (II), calcium (II), cadmium (II), chromium (III), iron (III), mercury (II), manganese (II), lead (II), strontium (II), thorium (IV) and zinc (II). An ion-exchange separation technique was employed to separate cobalt, copper and large amounts of iron, which were found to interfere. Nitroso-R salt is used as masking agent for cobalt in nickel-cobalt mixtures, and by that means nickel was determined in the presence of up to 12·5 mg. of cobalt.

Full details of procedure are given, with typical results obtained in estimation of nickel in the presence of various other ions.

Determination of Trace Amounts of Boron in Nickel

C. L. LUKE: 'Determination of Traces of Boron in Nickel.'

Analytical Chemistry, 1958, vol. 30, Aug., pp. 1405–6.

The scope of the method proposed by CHIRNSIDE *et al.* for determination of traces of boron in nickel (*Analyst*, 1957, vol. 82, pp. 18–24; *Nickel Bulletin*,

1957, vol. 30, No. 4, p. 50) is limited by the fact that the sample must be in the form of sheet or rod. It is also not applicable to all types of nickel, since no provision is made for removal of silicon and certain other metals which are known to interfere in the photometric curcumin method for estimation of boron. The present authors propose a technique which can be used for a wider variety of 'nickels'. The sample is dissolved, under a reflux condenser, in dilute hydrochloric acid containing a little platinic chloride. The boron is isolated by methanol distillation, and is determined by the photometric curcumin method.

Qualitative Determination of Nickel and Cobalt

R. E. D. CLARK: 'The Detection of Cobalt and Nickel in Qualitative Analysis.'

Analyst, 1958, vol. 83, July, pp. 431–2.

Nickel sulphide dissolves in alkaline solution of quinoxaline-2:3-dithiol, giving an intense red coloration, and cobalt sulphide dissolves in the same solution, to produce an orange-red coloration which masks the presence of nickel. In the presence of excess sodium sulphide, however, only nickel sulphide dissolves. These reactions can be used to detect cobalt and nickel in the black precipitate of sulphides, without the need for prior dissolution in acid. Full details are given of analytical procedure.

ELECTRODEPOSITION AND OTHER COATING METHODS

Effect of Oxide Films on Cathodes in Electrodeposition of Nickel

H. B. LINFORD and A. VENKATESWARLU: 'Cleaning and Preparation of Metals Prior to Electroplating. Effect of Oxide Films. XI. Effect of Oxides on the Adhesion of Electroplates.'

Plating, 1958, vol. 45, July, pp. 728–33.

Report issued under the aegis of *A.E.S. Research Project No. 12.*

Inorganic soils most frequently found on the surface of work which is to be plated consist of oxide films and residues left from cleaning media. Earlier studies of the influence of such contaminants, carried out on nickel-plated copper, had shown that:

(1) When oxidized copper cathodes were soaked in the Watts nickel solution prior to plating, significant dissolution of oxide occurred even at high pH values, producing a cathode film rich in copper ions, and that these copper ions electrodeposited with the first layer of nickel, producing an initial layer of a copper-nickel alloy.

(2) Electrochemical reduction of copper oxide consumed a large proportion of the current used in electrodeposition.

(3) Where oxide films thicker than 650 Å were present when the electrodeposition was begun (1000 Å before initial immersion in the nickel solution) appreciable quantities of oxide remained (presumably under the nickel) on the specimen after plating. The amount of residual oxide was found to increase with increase in thickness of the original oxide film.

In continuation of the above work, a study was made of the possible relationship between the thickness of the oxide film and the degree of adhesion obtained. This section of the research is the subject of the present report.

A detailed account is given of methods and equipment used for controlled oxidation and for plating. Adhesion was determined by a modified form of the Jacquet test (for original form see *Trans. Electrochemical Soc.*, 1934, vol. 66, pp. 393–418). Adhesion-test equipment is described and illustrated, with particulars of the technique employed. A table of results shows oxygen pick-up *vs.* adhesion. On the basis of the observations made, the following conclusions are considered to be generally valid:

The adhesion of nickel plating on copper was not affected by oxide films of a thickness up to 650 Å present before start of plating (up to 1000 Å before immersion in the plating solution). Anticipation of progressive decrease in adhesion with increasing thickness of film was found to be justified. There was a fairly regular relationship between adhesion and original thickness of oxide film, from an upper limit at which the bond was stronger than the basis metal, to the point of nil adhesion. With films more than about 2200 Å thick about 9 lb. force was required for detachment of the coating: beyond about 3600 Å the plating peeled spontaneously during vacuum drying, and a grey alloy of nickel with copper or cuprous oxide was clearly visible on the basis metal.

The results thus corroborated the findings of earlier investigations, indicating that adhesion problems will be encountered if more than 650 Å of Cu_2O is present at the beginning of electrodeposition. Since, however, an oxide film of the order of 200 Å thickness is readily detectable by the naked eye, it would appear easy for platers to avoid poor adhesion due to such contamination.

Bright Nickel-Plating Processes

Attention is directed to two bright-nickel-plating processes which are being introduced into the U.K.

(1) A process known in the U.S.A. as 'Nickel-Lume' or 'Levelume' is being pioneered (by arrangement with Hanson-van Winkle-Munning Company) by Albright and Wilson (Mfg.), Ltd., under the designation 'Plusbrite'.

(2) A ductile bright-nickel-plating solution, available in two main types, 'M.101' for use with mechanical cathode agitation, and 'A.101' for use with air agitation, is being marketed by R. Cruickshank, Ltd., under an agreement with Hanson-van Winkle-

Munning Company, and with Dr. Kampschulte, of Germany.

Broad indication has been given of the characteristics of the two processes. In both cases it is claimed that the deposits have a good degree of ductility, that good levelling is obtained, and that the nickel coatings are particularly suitable for subsequent chromium plating.

For details see:

(1) *Metal Industry*, 1958, vol. 93, July 4, p. 10.

(2) *Electroplating and Metal Finishing*, 1958, vol. 11, July, p. 257.

Stress in Electrodeposited Nickel

J. B. KUSHNER: 'Factors Affecting Residual Stress in Electrodeposited Metals.'

Metal Finishing, 1958, vol. 56, Apr., pp. 46–51; May, pp. 82–7; June, pp. 56–60; July, pp. 52–5, 59.

Experience has shown that residual tensile stress in electrodeposited metals may (1) cause peeling, tearing and blistering of the deposits; (2) result in serious distortion of light-gauge basis metals and electroformed parts; (3) accelerate corrosion and corrosion cracking; and (4) deleteriously affect the fatigue life of the basis metals. In spite of the obvious practical importance of the subject, and of the possibility of deriving valuable information on the structure of an electrodeposited metal from its stress behaviour, relevant data are limited and are based in the main on widely varying experimental conditions. The origin of residual stress is thus still relatively obscure. The purpose of the investigation reported in this paper, which is based on experimental work and supplemented by a literature review (*bibliography* of 63 items), was 'to obtain more definite relationships between residual stress and causative factors, as determined under a standard set of operating conditions, and to examine these results, and those of other workers in the field, critically and analytically, in an attempt to bring some of the aspects of the subject into sharper focus'. (The diversity of the theories which have been advanced to account for the phenomenon is illustrated by an introductory survey of the most important of the views at present held. These variously attribute stress to introduction of hydrogen into the lattice during deposition, to the presence of excess energy, or to occluded matter, e.g., hydrate formation.)

In most of the author's experiments nickel was used, because of the ease with which it is deposited, the large variations in stress which can occur in such deposits, and the mass of data available on the physical properties of nickel coatings. The solutions were operated at a pH of 4 and a temperature of 25°C. Copper was the cathode material. Residual stress was measured by the 'Stresometer', an apparatus invented by the author. Full details are given of the experimental procedures used.

The scope of the investigation and the results obtained are indicated in the following paragraphs.

(1) Relationship between Residual Stress and Deposit Thickness

The results confirmed data in literature reports. In the initial stages of deposition stress is high, diminishing to a limiting value after a certain thickness of metal has been deposited. It is postulated that this gradual change is due to the influence of two factors: (1) the basis-metal surface, and (2) the nature and composition of the cathode film. The author suggests the following equation to express the average stress in an electrodeposit:

$$S_a = A + Be^{-kt},$$

where S_a is the average stress at the thickness t, A is the equilibrium stress or limiting value of the stress for the given condition of operation, B is the stress due to the influence of the surface, and k is a constant expressing the rate of damping, equivalent to the inverse of some characteristic length. This equation was confirmed experimentally, and it is suggested that the values A and k should be quoted in any comparison of stress behaviour.

(2) Effect of the Cathode Film

As soon as deposition commences anions may be present in the electric double layer which is formed at the cathode, together with the diffusion layer. Since the anions can cause mechanical and electrical hindrance to the discharge of metal ions, they should have a relatively strong effect on the activation overpotential (metal overvoltage, as distinguished from hydrogen overvoltage). If excess energy were the cause of stress (a view which forms the basis of some theories of stress), use of fluoborate ions in a nickel solution should give rise to a higher stress than chloride ions, due to the greater activation overpotential of the former. Determination of residual stress in nickel deposited from various solutions revealed, however, no relationship between stress and anions, a finding which is presumed to invalidate the 'excess-energy' theories.

(3) Effect of Temperature

Although it is known that residual stress decreases with rise in temperature, no information was available on the effect of very low temperatures. Tests were therefore carried out on nickel deposits produced from a sulphamate bath at temperatures of 1·4°, 10·5°, 18°, 25° and 40°C. Cathode efficiency was checked, and results for each temperature were plotted in terms of residual stress and thickness. Very low temperatures proved to have a significant effect on the cathode film, greatly decreasing cathode efficiency and producing very high stresses in the interfacial region (100–200 Å).

(4) Effect of Current Density

Within the normal operating range, residual stress gradually increases with rise in current density. To determine the effect of a very low current density, a value of 0·30 amp./sq. ft. (0·032 amp./dm.²) was used. The effect was similar to that of low temperatures: a high tensile stress was produced, though to a lesser degree.

(5) Effect of Contaminants and Addition Agents

The influence of impurities and addition agents was determined by addition of 0·25 g./L. of ferric sulphate to a Watts solution. Within one minute, stress had risen from the normal 16,000 p.s.i. (7 t.s.i.; 11 kg./mm.^{2}) to 17,700 p.s.i. (7·5 t.s.i.; 12 kg./mm.^{2}), increasing eventually to 24,000 p.s.i. (10·5 t.s.i.; 17 kg./mm.^{2}). Addition of saccharin to a nickel-fluoborate solution had no stress-reducing effect in the initial stages of deposition, and the conclusion is drawn that, while adsorption and compound formation account for many of the observed phenomena, it is likely that contaminants present in such small quantities as was the saccharin can have so great an influence only by being brought up to the cathode diffusion film and concentrated there through electrical migration.

(6) The Rôle of the Metal Surface

(a) *Surface Cleanliness and Adhesion*

Since the stress developed at the beginning of plating is a measure of bond strength between basis metal and deposit, it was postulated that poor bonding would reveal itself in the stress values obtained. This hypothesis was verified by tests on two stainless-steel discs, one properly cleaned before nickel plating, the other with a surface oxide film. The poor bonding obtained with the latter specimen was reflected in low initial stress values. On the basis of these findings it is suggested that the residual-stress/thickness curve would provide a means of measuring bond strength: the height of the ordinate at a certain thickness of deposit (e.g., 0·0001 in.: 0·0025 mm.) would then be taken as a criterion of this property.

(b) *Surface Finish and Residual Stress*

To determine the effects of surface finish, copper discs, some annealed, and having finishes which varied greatly (e.g., electropolished or as-rolled), were plated from a nickel-sulphamate solution. The results showed that this variable had no significant influence on residual stress.

(c) *Effect of Grain Size*

Discs, annealed in such a manner as to induce grain growth, were subjected to tests parallel with some of those previously described. It was found that as the grain size increased the region of maximum stress moved farther away from the interface. This phenomenon is explained in terms of the preferential growth of the electrodeposited metal at the grain boundaries, which are disorganized regions and probably contain groups of atoms the spatial arrangement of which is likely to conform to its own lattice pattern. The coarser the grains, the more limited are such sites, and, since growth now to a large extent starts within the grains of the basis metal, the longer will be the time needed for the crystals of the deposit to counteract the effects of this less suitable atomic arrangement, and to revert to their normal crystal structure.

(d) *Nature of the Substrate Metal*

Experiments in which copper was deposited on a nickel substrate, and *vice versa*, illustrated the influence of the nature of the basis metal, *per se*, on the amount and type of initial residual stress in the deposit. Nickel, which has a smaller lattice parameter than copper, was initially deposited in a state of tensile stress on the latter metal. When nickel was coated with copper the initial stress was compressive.

(7) Stress After-Effect and Hydrogen Uptake

It had been noted in the literature that tensile stresses in a deposit in tensile stress increase slightly when the current is shut off, and that on stoppage of current stresses which are compressive tend to become more tensile. These 'after-effects' were studied in a number of deposits and the results were plotted as a function of time. They are explained in terms of the formation of a concentration cell which causes some dissolution of metal and its re-deposition, but which, simultaneously, releases some of the foreign matter at the grain boundaries, so that the stress becomes more tensile.

From the results of other experiments it is concluded that hydrogen pick-up is not the major cause of residual stress.

The paper ends with a discussion of a theory which the author advances to account for residual stress in electrodeposits. The theory involves two mechanisms: (1) lattice misfit in the initial layers of the deposit; and (2) interference by the water content of the solution.

Corrosion-Resisting Properties of Decorative Nickel Plating

C. H. SAMPLE: 'Developments in Decorative Plating.' *Plating*, 1958, vol. 45, July, pp. 721–7.

Reprint of paper presented to *Society of Automotive Engineers*, Jan. 1958: see abstract in *Nickel Bulletin*, 1958, vol. 31, No. 5, p. 128.

Effect of Nickel Undercoatings on Oxidation-Resistance of Enamelled Steel

H. G. LEFORT and A. L. FRIEDBERG: 'Quantitative High-Temperature Oxidation of Porcelain-Enamelled Iron.'

Jnl. Amer. Ceramic Soc., 1958, vol. 41, June, pp. 216–26.

In recent years porcelain-enamel or ceramic coatings have been the subject of investigation in many fields of industry, mainly as a means of conferring increased oxidation-resistance on components working at elevated temperatures. Although some attempts have been made to obtain quantitative data on the degree of protection provided by various grades of enamel (published literature is reviewed in the present paper), most evaluations have been qualitative, and based on visual assessment. The investigation now described was planned with the

more specific aim of determining rate of oxidation, in air, of enamelled and un-enamelled specimens as a function of temperature, duration of exposure, and other variables.

'Enamelling iron' (cold-rolled low-carbon steel sheet) was used for most of the experiments, since it was assumed that the poor oxidation-resistance of this material would facilitate measurement of rate of oxidation. The porcelain enamel tested was that designated 'UI 285-1', selected as being known to provide excellent oxidation-resistance and to adhere well to nickel-plated material and to stainless steel. Oxidation rates were assessed by weight-gain of the specimens.

The influence of following variables was investigated:

(1) *Volatilization of the Enamel*

The enamel was exposed at 1800°F. (982°C.) for 50 hours under conditions which ensured that the only change in weight occurred in the enamel.

(2) *'Edge Effect'*

Since degree of oxidation was reported to be influenced to some extent by the corners and edges of the specimen, this factor (the 'edge effect') was taken into account by experiments, at 1800°F. (982°C.), on specimens of differing dimensions.

(3) *Undercoatings of Electrodeposited Nickel and Thickness of the Enamel Coating*

Previous reports on the beneficial effect of nickel plating, prior to enamelling, had dealt only with short-time high-temperature exposure. In the present work, which involved long-time exposure, the influence of the nickel undercoating was established by varying the thickness of the deposits and using, as controls, nickel-plated specimens which were not subsequently enamelled. Under similar conditions the effect, on the oxidation rate, of varying the thickness of the enamel, was assessed by applying two normal 4–4½ mil coatings to some of the test specimens.

(4) *Surface Preparation of the Basis Metal*

The majority of the tests were carried out on specimens the surfaces of which, prior to nickel plating and/or enamelling, had been mechanically abraded and chemically cleaned, but in some tests the surfaces of the specimens were sand-blasted.

(5) *Temperature of Exposure*

The specimens were exposed, in an air environment, at three temperatures: 1850°, 1700° and 1600°F. (1010°, 927° and 871°C.). Uncoated, porcelain-enamelled and nickel-plated specimens and specimens porcelain-enamelled over a nickel undercoat were exposed. The influence of surface preparation and of thickness of the coating was evaluated by tests at 1600° and 1700°F. (871° and 927°C.).

For comparative purposes, supplementary tests were made, at 1700° and 1850°F. (927° and 1010°C.), on bare and porcelain-enamelled specimens of stabilized 18-8 chromium-nickel stainless steel. For these tests the surfaces of all the specimens were sand-blasted and only one coat was applied to enamelled samples.

The data, presented in the form of curves depicting gain in weight as a function of time and temperature, led to the conclusions summarized below:

(1) The volatilization which occurred in the porcelain enamel had little effect on the oxidation rate of the carbon-steel specimens, but apparently exerted some influence on the slight gain-in-weight values for the enamelled stainless steel.

(2) No significant correlation was found between area-to-perimeter ratio of the specimen and rate of oxidation.

(3) For a given time of exposure, oxidation rate of specimens nickel-plated prior to enamelling decreased with increase in the thickness of the nickel deposit (up to an amount corresponding to 0·7 gm./sq. ft.) but reduction so effected was not great compared with that achieved by increasing the thickness of the enamel coating. At 1700° and 1600°F. (927° and 871°C.) the rate of oxidation of specimens carrying two coats of enamel was only half that recorded for a single-coat specimen at the same temperatures.

(4) Sandblasting before enamelling (*vis-à-vis* abrasion and chemical cleaning) resulted in a small decrease in the oxidation of the iron specimens at 1700°F., but at 1600°F. the effect was insignificant.

(5) The difference between the oxidation rates of enamelled and of unenamelled iron specimens was large at 1600°F., less pronounced at 1700°F., and slight at 1850°F.

(6) Under the test conditions, both the enamelled and control specimens oxidized first at a linear rate, and, after a certain gain in weight, at a parabolic rate until the limit of oxidation was approached.

Plating of Titanium

'Multi-Layer Plating on Titanium.'

Metal Industry, 1958, vol. 93, July 25, p. 78.

This short article gives notes, in general terms, on a method developed by North American Aviation, Inc., for production of adherent coatings on titanium, thus facilitating the utilization of the high strength/weight ratio of the metal without the introduction of difficulties arising from its chemical characteristics. The coatings also usefully prevent galling and seizing during forming, and scaling during heat-treatment, facilitate soldering, and permit reclamation of over-machined parts.

The method developed involves four stages: electroless deposition of a coating of nickel, to secure the requisite adhesion to the base metal; electrodeposition of copper, to form an undercoat for the third layer, which is silver, and final plating with gold, to obtain

the necessary oxidation-resistance. The nickel and copper underlays range in thickness from 0·001 (0·025 mm.) to 0·002 in. (0·05 mm.); the silver layer is of the order of 0·002 to 0·0025 in. (0·0625 mm.), and the final gold coating is only about 0·000050 in. (0·00125 mm.) in thickness. Typical parts for which the process is used are illustrated.

Ductility Test for Electrodeposited Coatings

J. EDWARDS: 'Spiral Bending Test for Electrodeposited Coatings.'

Trans. Inst. Metal Finishing, 1958, vol. 35, Summer, pp. 101–6.

The method of determining the ductility of electrodeposited coatings by tensile tests on specimens detached from the basis metal, although accurate, is laborious, and unsuitable for routine testing. For many purposes, a reasonable measure of the ductility of a deposit is provided by the degree to which it resists cracking when the plated composite is subjected to deformation.

In this paper the author gives details of such a test, which offers the additional advantage that it requires little equipment. (The information presented has been previously made available confidentially to members of the British Non-Ferrous Metals Research Association.) The technique described has given results sufficiently accurate and reproducible to prove useful in many investigations.

The test is carried out by bending a plated strip round a former having the shape of an equiangular (logarithmic) spiral, the surface of which is graduated directly in terms of radius of curvature. The value at which cracking begins is used, in conjunction with the thickness of the strip, to calculate percentage elongation at that point. The construction of the former, preparation of specimens and test procedure are fully described.

That the bending test might also provide a useful means of solution control is indicated by the consistent results obtained in the course of investigations in which the composition of two precisely controlled organic bright-nickel-plating solutions was correlated with routine determinations of the ductility of the deposits produced from them. Addition of the standard brightening agent to the solution, or a decrease in the pH, consistently resulted in fall in the elongation values of the deposit: introduction of a corrective agent used in maintenance of the bath caused an increase in brightness, improvement in elongation and a decrease of internal stress. The presence of impurities in the solution was reflected in gradual decrease in ductility as revealed by the bend test. Experience in using the test in some commercial plating shops, confirmed by further work in the B.N.F.M.R.A. laboratories, has demonstrated the potential usefulness of the method in routine control, but indicated the need for closer standardization of test procedure.

Measurement of Thickness: Review and Bibliography

See abstract on p. 256.

NON-FERROUS ALLOYS

Martensitic Transformations in Nickel-Aluminium Bronze

D. HULL and R. D. GARWOOD: 'The Martensite Transformations of the Beta Phase in Copper-Aluminium-Nickel Alloys.'

Jnl. Inst. Metals, 1957–58, vol. 86, July, pp. 485–92.

'Two types of martensite transformation of the metastable β phase have been observed in an alloy containing copper 79·5, aluminium 12·8, nickel 7·7, per cent. When the quenched alloy is cooled to 0°C. the plates formed are relatively fine and free from substructure (β′), but on tempering the quenched alloy and subsequent cooling to room temperature a coarse-grained product (γ′), with a distinct secondary structure, is formed. Both types of martensite form isothermally when the alloy is aged at room temperature after a suitable heat-treatment. This fact and the conditioning of the β phase for transformation into γ′ martensite, which occurs during tempering, are thought to be due to the growth of the ordered domains of the Cu_3Al superlattice. The shear angle of the associated shape deformation is different for the two martensite products.'

Nickel-Aluminium Bronze: The 'Superston' Series

'Superston Bronze.'

Machinery (Lond.), 1958, vol. 92, June 27, pp. 1509–10.

Following the development and successful use, in marine-engineering applications, of 'Novoston' nickel-aluminium bronze, a further kindred series of copper-base alloys, the 'Superston' bronzes, has been recently introduced into other branches of industry by Messrs. J. Stone and Company, Ltd. The basic constituents of the 'Superston' bronzes (proportions of which are varied to obtain the characteristics desired for specific applications), fall within the following percentage limits: manganese 11–13, aluminium 7–9, iron 2–4, nickel 1·5–5, copper balance. Melting points are in the range 950°–990°C. (*vis-à-vis* 1060°–1080°C. for aluminium bronze); tensile strengths vary from 45 to 55 tons per sq. in. (71–86·5 kg./mm.²), i.e., they are comparable with those typical of aluminium bronzes and high-tensile brasses. This article describes the properties which render the complex nickel-aluminium-iron bronzes superior to straight aluminium bronzes.

'Superston 40', the most widely used of the alloys, has a U.T.S. of 45 tons per sq. in. (71 kg./mm.²), a proof stress in excess of 20 tons per sq. in. (31·5 kg./mm.²) and an elongation, in the as-cast condition, of 30–35 per cent. 'Superston 60' is employed where greater tensile strength is needed, but this alloy is less ductile. 'Superston 44' is suitable for service at elevated temperatures: at 450°C. it has a short-time tensile strength of 25 tons per sq. in. (39·5 kg./mm.²).

It is pointed out that although high-tensile brasses may have somewhat similar mechanical properties, they are inferior to the complex bronzes in corrosion-resistance; they are, for example, susceptible to stress corrosion. With respect to galvanic corrosion the behaviour of the 'Superston' alloys differs little from that of other bronzes: their general corrosion-resistance is, however, greater.

The 'Superston' bronzes have casting characteristics which enable advantage to be taken of their high strength, in that thin-section castings are readily produced, with resultant saving in weight, cost and machining time. The alloys may be cast in sand, shell or semi-permanent moulds and can also be used for centrifugal and gravity die castings.

The article includes details of cutting speeds, feeds and tools which have proved suitable for machining the bronzes, and notes are also given on their cold- and hot-working properties. Mechanical properties can be varied by appropriate heat-treatment: a hardness of 350 Brinell is obtainable in the 'Superston 40' bronze. The alloys are weldable with rods similar to those used for aluminium bronze, and a special 'Superston' rod is also available.

Nickel-Chromium-Aluminium-Niobium Alloys

See abstract on p. 268.

Nickel-Titanium Alloys

See abstract on p. 268.

Mechanical Properties of 90-10 Copper-Nickel Alloys

R. B. NIEDERBERGER: 'Mechanical Properties of 90–10 Copper-Nickel Alloys.'
U.S. Naval Engineering Experiment Station, Annapolis, Report 4E(*B*-1)101717; 11 pp. + figures. *P.B.* 127911.

Sea-water corrosion-erosion tests had earlier been carried out on an iron-containing 90–10 cupro nickel (in the form of condenser tubes, welded sheet, and pipe) to determine the suitability of this alloy as a substitute for 70–30 copper-nickel. The satisfactory corrosion-resistance exhibited by the alloy prompted study, for specification purposes, of its mechanical properties, in the form of rod and plate. The results of this investigation are given in the present report.

The rod material was tested in the soft, half-hard and hard conditions; the plate was hot-rolled. The test programme involved:

(1) Tensile tests on rod material at room and elevated temperatures (up to 800°F.: 425°C.), and on sheet at room temperature;

(2) Flexural- and torsional-fatigue tests on the rod material;

(3) Bend tests on rod and plate material;

(4) Tensile tests on rod annealed at 1400°F. (760°C.) for one hour, followed either by air-cooling or quenching;

(5) Tensile tests on tube, sheet and plate material from the batches used to provide corrosion-test specimens.

The conclusions reached, relative to mechanical properties, are as follows:

'The tensile properties of the material decrease uniformly with rise in testing temperature up to 800°F. (425°C.). At this temperature tensile strength ranges from 29,000 p.s.i. (13 t.s.i.; 20·5 kg./mm.²) for soft material to 45,000 p.s.i. (20 t.s.i.; 31·5 kg./mm.²) for hard material.

'The ratio of endurance limit, at 10 million cycles of reversed bending, to tensile strength is approximately 0·36 for all tempers tested. Endurance limit in alternating torsion was not increased by cold work, being 11,000 p.s.i. (5 t.s.i.; 8 kg./mm.²) at 10 million stress cycles for all three temperatures of the 1 per cent. iron material. At the same number of cycles the endurance limit of the higher-iron material in the soft condition was 14,000 p.s.i. (6 t.s.i.; 10 kg./mm.²).

'The yield strength of the hot-rolled 1·4 per cent. iron alloy was approximately one-third greater than that of the 1·0 per cent. iron alloy. The yield strength of the 1·4 per cent. iron alloy is appreciably affected by cooling rate following annealing, being higher for air-cooled than for water-quenched material. The tensile properties of the 1·0 per cent. iron alloy are unaffected by the cooling rate.'

Resistance of Nickel Alloys to Corrosion by Caustic Alkalies

See abstract on p. 272.

Determination of Zinc in High-Nickel Alloys

F. RAVAULT and N. R. WILKINS: 'The Determination of Traces of Zinc in Nickel Alloys.'
Foundry Developments, 1958, Apr., pp. 29–32.

The authors describe a method for the determination of small amounts of zinc in nickel-chromium alloys. The zinc is separated from the principal interfering elements by using the chloride form of an anion resin ('Amberlite I.R.A. 400 (Cl)') and is finally determined by a polarographic method. Concentrations of zinc as low as 0·0005 per cent. may be determined. The procedure is applicable also to nickel-copper alloys such as 'Monel' and cupro-nickel.

NICKEL-IRON ALLOYS

Martensite Transformation in Nickel-Iron-Alloy Powders

R. E. CECH and D. TURNBULL: 'Shock-Induced Martensitic Transformation.'
Trans. Metallurgical Soc., Amer. Inst. Mining, Metallurgical and Petroleum Engineers, 1958, vol. 212, June, pp. 395–7.

Previous studies on martensitic transformations in nickel-iron alloys have indicated that in polycrystals transformation in one grain tends to induce a similar change in other grains.

This later work was done on single-crystal spheres of iron-nickel alloy containing 28·6 at. per cent. nickel, used in particles of 10–20 micron size. The behaviour of such material was studied in comparison with that of bulk iron-nickel alloy of comparable composition.

The results show that such particles can be cooled as much as 186°C. below the M_S temperature of the bulk alloy without undergoing martensitic transformation. Particles which resist transformation by direct quench are, however, transformed isothermally at a temperature below bulk-alloy M_S temperature if slight vibration is applied. Susceptibility to vibration-induced transformation is greatest at a temperature of −148° to −160°C. Under quiescent conditions initiation of the martensitic transformation isothermally occurs at an immeasurably slow rate.

Diffusion of Nickel in Liquid Iron Saturated with Carbon

R. E. GRACE and G. DERGE: 'Diffusion of Third Elements in Liquid Iron Saturated with Carbon.' *Trans. Metallurgical Soc., Amer. Inst. Mining, Metallurgical and Petroleum Engineers*, 1958, vol. 212, June, pp. 331–7.

Report of measurements, by the capillary-reservoir technique, of the chemical-diffusion coefficients of sulphur, nickel, titanium, manganese, phosphorus and silicon in dilute solutions of carbon-saturated liquid iron. Temperature coefficients are reported for the interval 1190°–1450°C. The coefficients increase from $D = 1{\cdot}1 \times 10^{-5}$ to 15×10^{-5} cm.^{2} per sec., in the order sulphur, nickel, titanium, manganese, phosphorus, silicon. At 1350°C. the relative rates of diffusion are silicon〉phosphorus〉manganese〉titanium〉nickel〉sulphur. The variation in diffusivity is much greater than would be derived from relevant theoretical calculations. Some data are also presented for average diffusion coefficients of carbon in liquid iron-carbon alloys.

CAST IRON

Elevated-Temperature Properties of Cast Iron

AMER. SOC. TESTING MATERIALS: 'Properties of Cast Iron at Elevated Temperatures.'
Contained in *Report of Joint A.S.T.M.-A.S.M.E. Committee on Effect of Temperature on the Properties of Metals.*

A.S.T.M. Preprint 68, June 1958, pp. 5–6.

Under the aegis of the Joint Committee a study has been made of the properties of cast iron in the temperature range 800°–1000°F. (425°–540°C.), in order to assess the suitability of low-alloy cast irons for use, under load, at temperatures above the maximum of 650°F. (343°C.) at present specified. The report of the investigation, of which these notes give a brief outline, will be published as an *A.S.T.M. Special Technical Publication.*

Seven cast irons were subjected, at 800° and 1000°F. (425° and 540°C.), to tension, creep-rupture, thermal-shock and growth tests:

As-cast molybdenum-alloyed grey iron;
As-cast nickel-molybdenum-alloyed grey iron;
Fully-annealed chromium-alloyed grey iron;
Ferritic unalloyed nodular iron (S.G. iron);
As-cast chromium-nickel-molybdenum-vanadium-alloyed grey iron;
As-cast unalloyed grey iron;
Subcritically-annealed chromium-molybdenum-alloyed grey iron.

In general, the alloyed irons are considered to hold promise for long-time service under load, and for applications involving thermal shock, at temperatures up to a maximum of 800°F. (425°C.). Although the materials tested are not suitable for such applications at a temperature as high as 1000°F., (540°C.) results indicate that development of low-alloy cast irons with high-temperature properties adequate at such temperatures is well within the bounds of possibility.

Variation in alloying elements was found to have a marked effect on elevated-temperature properties. Molybdenum appeared to have the most beneficial influence on creep-rupture properties, nickel was specially effective in improving thermal-shock properties, and chromium increased structural stability.

U.S. Bureau of Ships: Foundry Manual

U.S. BUREAU OF SHIPS: 'Foundry Manual.'
U.S. Navy Dept., Publn. NAVSHIPS 250-0334, Jan. 1958; 291 pp.

The scope of this publication, intended primarily for use by foundry personnel aboard repair ships and tenders, is indicated in the following extract from the preface.

'The Manual is divided into two general sections. The first section, chapters 1–13, contains information of a general nature, such as

How Metals Solidify,
Designing a Casting,
Sands for Moulds and Cores, Gates, Risers and Chills, and
Description and Operation of Melting Furnaces.

Subjects covered in these chapters are generally applicable to all the metals that may be cast aboard ship.

'The second section, chapters 14–21, contains information on specific types of material, such as

Copper-base Alloys,
Aluminium-base Alloys,
Cast Iron,
Steel.

Specific melting practices, suggestions for sand mixes, moulding practices, gating and risering are covered.

'This manual has been written with the 'how-to-do-it' idea as the principal aim. Discussions as to the 'why' of certain procedures have been kept to a minimum.'

The first section also contains a chapter on the compositions and typical applications of alloys and steels frequently used for cast marine components; this chapter is supplemented by charts summarizing the requirements of relevant U.S. Military and Navy Specifications. Pouring, cleaning and heat-treatment of castings are also dealt with.

The remaining chapters of the second section relate to

Nickel-base Alloys ('Monel' and 'S-Monel')
Copper
Babbitting with Tin-base Bearing Metal
Process Control

The information contained in the text is supplemented by more than 250 illustrations.

CONSTRUCTIONAL STEELS

Effect of Neutron Irradiation on Mechanical Properties of Low-Alloy Nickel Steel

L. P. TRUDEAU: 'Effect of Neutron Irradiation on Mechanical Properties of Ferritic Steels.'
Sixth U.K./Canada Tech. Conference, Ontario, Oct. 1957.
Atomic Energy of Canada Ltd., Report UK/C6/108; 4 pp. + figures.

One object of this investigation was to study the influence of composition and microstructure on changes induced in the mechanical properties of ferritic steels by irradiation: a second was to determine the effects of using progressively greater integrated fluxes; a third was to obtain data on the behaviour of the steels when annealed subsequent to irradiation. Irradiation and testing are still in progress: the results now reported are from the early stages of the test programme.

Of the pressure-vessel steels included in the investigation, two form the subject of this report; an aluminium-killed 0·17 per cent. carbon steel, and a U.S. Navy low-alloy steel ('HY-65') of the following percentage composition: carbon 0·12, silicon 0·21, manganese 0·48, sulphur 0·032, phosphorus 0·013, nickel 2·16, molybdenum 0·39, vanadium 0·11, copper 0·70. The 'HY-65' steel was investigated in three conditions of heat-treatment: (1) normalized at 1750°F. (955°C.) and tempered for one hour at 1225°F. (663°C.); (2) austenitized at 1750°F., brine-quenched, tempered for one hour at 1225°F.; (3) austenitized at 1750°F., austempered in the range 700°–800°F. (370°–425°C.), and tempered for one hour at 1225°F. The as-tempered hardnesses were, respectively, Rockwell C 16·3, 29·7 and 25·9.

The report is concerned only with the results of notch-impact tests, which are considered in the light of the effect of irradiation on the ductile-brittle transition temperature. (No tensile testing had been carried out at the date of the report.)

In discussing the results, the author emphasizes that shifts in transition temperature resulting from irradiation relate to mid-range energy values, and that the specimens used were smaller than normal Charpy test pieces. Transition-temperature shifts for the 'HY-65' steel may be correlated with heat-treatment as follows: quenched-and-tempered condition, 137°C.; austempered-and-tempered condition, 176°C.; normalized-and-tempered condition, 196°C. The quenched-and-tempered structure thus appears to offer best resistance to irradiation, but it is considered possible that the higher initial hardness of the sample might have had some influence in this connexion. Maximum energy absorption in the ductile region fell somewhat more markedly in the alloy steel than in the mild steel. In the normalized un-irradiated condition the 'HY-65' material had a transition temperature about 26°C. lower than that for the mild steel, but after irradiation this temperature was about 44°C. higher, despite the somewhat greater irradiation to which the mild steel had been subjected.

Experiments on irradiated carbon steel indicated that annealing at 335°C. produced a marked improvement in the impact properties, but no un-irradiated control sample had been heated to the same temperature for comparison.

Effect of Tempering Temperature on Impact Properties of High-Purity Nickel-Alloy Steels

J. M. CAPUS and G. MAYER: 'Impact Properties of High-Purity Nickel-Chromium-Molybdenum Steels.'
Jnl. Iron and Steel Inst., 1958, vol. 189, July, p. 255.

For many low-alloy steels, in the hardened-and-tempered condition, the curve relating room-temperature impact strength and tempering temperature shows minimum impact resistance after tempering at 250°–400°C., an effect known as 'Izod-trough' embrittlement. It has been demonstrated that high-purity nickel-chromium steels are immune to embrittlement on prolonged re-heating at about 450°C. after tempering at higher temperatures (*Nature*, 1956, vol. 178, p. 433: *Nickel Bulletin*, 1956, vol. 29, No. 10–11, p. 191) and the work now reported was carried out to determine whether this immunity would extend also to 'Izod-trough' embrittlement.

The compositions (wt. per cent.) of the two high-purity steels, which were melted and cast *in vacuo*, are given on p. 267.

Test specimens were heat-treated at 850°C. for one hour, oil-quenched, tempered for ½ hour at temperatures which ranged (at intervals of 50°) from 150° to 550°C., and finally water-quenched. Impact values were determined, in duplicate, at 20° and at −78°C.

The data obtained, presented in the form of curves relating hardness and impact values to tempering temperatures, show that neither steel exhibited an 'Izod trough', and that the steel containing 0·28 per cent. carbon gave room-temperature impact values of at least 35 ft.-lb. (4·83 kg.m.) for all tempering temperatures. The tensile properties of the steels did not differ significantly from those typical of steels of commercial purity.

Supplies of Nickel

World output of nickel has now overtaken demand. Industry can therefore plan ahead, safe in the knowledge that nickel is available and **will continue to be available.**

An important contribution to this improved situation will be made by the new nickel deposits now being developed in Manitoba by The International Nickel Company of Canada Limited

Compositions of High-Purity Nickel-Chromium-Molybdenum Steels

(*See abstract on p. 266*)

C %	Si %	Mn %	S %	P %	Ni %	Cr %	Mo %
0·28	0·05	<0·02	0·003	0·005	1·4	1·1	0·23
0·42	0·04	<0·02	0·003	0·006	1·53	1·09	0·24

Correlation of Izod, Charpy U-Notch and Charpy V-Notch Tests on Nickel-containing Steels

A. W. JOHNSTON: 'Comparison of Notched-Bar Tests.'
Engineering, 1958, vol. 186, July 25, p. 107.

In an attempt to establish some relationship between the results of Izod, Charpy U-notch and Charpy V-notch tests, over 1,200 tests have been made, on standard and subsidiary-standard test specimens of the following six steels: 0·07, 0·10 and 0·15 per cent. carbon steels, 2½ and 3½ per cent. nickel-chromium steels, and 1 per cent. nickel steel containing 0·4 per cent. carbon. The tests were carried out at temperatures between 110° and 196°C. (i.e., within the ductile-brittle temperature ranges of the steels). This note summarizes, as follows, conclusions presented in the full report (available from the *Mechanical Engineering Research Laboratory, East Kilbride, Glasgow*; Ref. *A.B. Div. No.* 9/58):

'(1) No simple relationship applicable to all six materials tested appears to exist between the results of the Izod test, the U-notch Charpy test and the V-notch Charpy test.

'(2) The relationship between Izod and U-notch Charpy test results proposed in B.S. 131:1933 was satisfied only by the results from the three alloy steels. A different relationship, of similar form, was found for the three mild steels.

'(3) No simple relationship applicable to all six materials appears to exist, for any of the three tests, between the absorbed energies for 10 mm. × 10 mm. test pieces and 10 mm. × 5 mm. test pieces.

'(4) An approximate relationship of linear form was found for specimens of the two sizes used in Izod tests on four of the steels.

'(5) When 10 mm. × 10 mm. test pieces are used the transition from ductile to brittle fracture occurs in all the steels at a higher temperature with Charpy V-notch than with Charpy U-notch specimens. This finding is applicable to the three mild steels also when 10 mm. × 5 mm. test pieces are used.

'(6) Transition curves obtained from Izod and Charpy U-notch tests extend over approximately the same range of temperatures.

'(7) The energies absorbed by test pieces cut from the test bars in a transverse direction are, in general, lower than those from test pieces cut in a longitudinal direction.'

Martensite Transformation in Nickel-Iron-Alloy Powders

See abstract on p. 264.

Corrosion of Metals in Marine Tropical Atmospheres

See abstract on p. 272.

Combined Nitriding and Induction-Hardening of Nickel-Alloy Steels

P. M. UNTERWEISER: 'Combine Nitriding, Induction Hardening on Low-Alloy Steel.'
Iron Age, 1958, vol. 181, June 19, pp. 122–4.

Unusual degrees of surface hardness can be obtained in nickel-alloy steel of the S.A.E. 4340 type by application, after nitriding, of a high-frequency induction-heating cycle. Treatment for about 2 seconds suffices to increase the hardness of the nitrided surface from Rockwell C 57 to Rockwell C 64. The induction-hardening treatment causes deeper diffusion of the nitrogen, and thus provides a greater depth of hardening. Core and case hardnesses obtainable are illustrated in this article and data are presented on depth of penetration. The hardness of the doubly-treated steels is not lowered by a stress-relief treatment of one hour's duration. Surfaces so produced are highly wear-resistant and it is anticipated that the new technique will find application in treatment of various carbon and low-alloy steels.

Determination of Boron in Steels

BRIT. IRON AND STEEL RESEARCH ASSOCN.: 'The Determination of Boron in Carbon and Low-Alloy Steels.'
Jnl. Iron and Steel Inst., 1958, vol. 189, July, pp. 227–32.

The quinalizarin method has provided an effective means of determining boron in steels which do not contain appreciable amounts of other alloying elements. (This procedure does not involve separation of boron from iron, and the latter element interferes only in so far as ferrous salts precipitate in the concentrated-sulphuric-acid solution used for the colour test.) The high sensitivity of the technique ensures satisfactory qualitative determination, but doubt exists as to the accuracy of the quantitative results obtained, because the colour formed is critically dependent on the amount of water present in the sulphuric-acid solution. Since it is recognized that boron in amounts as low as 0·001–0·005 per cent. can cause considerable variation in the mechanical properties of steels, the terms of reference adopted

by the Methods of Analysis Committee of the British Iron and Steel Research Association (under whose aegis the investigation was carried out) specified development of a method for determination of boron in amounts up to 0·01 per cent., with an ideal reproducibility of ±0·0002 per cent., and applicable to steels of the 3 per cent. chromium and 2½ per cent. chromium-nickel-molybdenum types.

Preliminary examination of the quinalizarin procedure indicated that development of a direct method which would satisfy these requirements was unlikely. The problem therefore resolved itself into one of separation and subsequent determination of boron. Separation was attempted by two techniques: (1) distillation as methyl borate, (2) removal of other metals by ion-exchange resins, leaving boron in solution. Final determination of boron was, to a certain extent, governed by the type of separation used, and involved study of an absorptiometric technique using curcumin or dianthrimide. The extent to which the procedures could be used to determine soluble and insoluble boron was also taken into account.

The procedure finally recommended (full details of which are given), is based on removal of metal ions from a solution of the sample by a cation-exchange resin, and subsequent absorptiometric determination of boron in the eluate by means of dianthrimide.

The method is applicable to determination of 0·0005–0·02 per cent. boron in mild and low-alloy steels (i.e., containing less than 2 per cent. chromium and less than 5 per cent. vanadium), and is claimed to have a reproducibility of ±0·0005 per cent. in the range up to 0·005 per cent. boron.

It has been tested mainly in connexion with mild steels, but work is currently being carried out on alloy steels. It will be reported later.

HEAT- AND CORROSION-RESISTING MATERIALS

'Nimonic 105': New Alloy in the 'Nimonic' Series

'Another 'Nimonic' Alloy.'

Engineer, 1958, vol. 206, Sept. 5, p. 366.

Henry Wiggin and Company, Ltd. has issued preliminary information on a new alloy in the 'Nimonic' series, designated 'Nimonic 105'. Like previous alloys in this group, 'Nimonic 105' was developed in the laboratories of The Mond Nickel Company, Ltd., in this case from the nickel-chromium-cobalt-molybdenum alloy 'Nimonic 100'.

The new alloy, which has been under test by various gas-turbine manufacturers and is now in production, is characterized by very high resistance to creep. At 940°C. and under 7 tons per sq. in. (11 kg./mm.²), life-to-rupture is of the order of 50 hours, compared with a life, under the same conditions, of 30 hours for 'Nimonic 100' and 15 hours for 'Nimonic 95'. 'Nimonic 105' offers the further advantage of increased resistance to a type of corrosion associated with contamination by solid or molten sulphates encountered in turbines operating at the gas temperatures involved in aircraft propulsion. It is emphasized that the fuels used in turbines operating in that temperature range are high-grade distillates which have little or no corrosive effects at lower temperatures, and that the type of corrosion to which they give rise differs from the vanadium-pentoxide attack which results, at much lower temperatures, from the use of residual fuel oil.

Nickel-Titanium Alloys

L. I. PRYAKHINA: 'Constitution and Properties of Alloys of the Nickel-Titanium System.'

Trudy Inst. Met. im A. A. Baĭkova, 1957, No. 2, pp. 119–25.

A study was made of the microstructure, hardness, electrical resistance and heat-resisting properties of twelve nickel-base alloys containing up to 16·62 per cent. of titanium. Solubility limits of titanium in nickel were found to be between 8 and 10·8 per cent. and alloys within this range showed maximum heat-resistance.

A summary of the results of the investigation is published in *Chemical Abstracts*, 1958, vol. 52, June 10, p. 8908.

Nickel-Chromium-Aluminium-Niobium Alloys

I. I. KORNILOV and L. I. PRYAKHINA: 'Hot Strength of the Quaternary Alloys of the Nickel-Chromium-Aluminium-Niobium System.'

Issledovan. po Zharoproch. Splavam, Akad. Nauk S.S.S.R., Inst. Met. im. A. A. Baĭkova, 1956, pp. 138–47.

The investigation covered alloys containing 10, 15, 20 and 30, per cent. of chromium, aluminium 6 per cent. and niobium 0–12·5 per cent. Determinations were made of specific electrical conductivity and hardness, and the structure of the alloys was examined. A summary of the results is given in *Chemical Abstracts*, 1958, vol. 52, June 10, p. 8907.

Dynamic Creep Properties of High-Temperature Alloys

F. H. VITOVEC: 'Dynamic Creep with Special Consideration of Strain-Rate Effects.'

Proc. Amer. Soc. Testing Materials, 1957, vol. 57, pp. 977–86.

With the increased use of alloys at elevated temperatures, the effect of superimposed alternating stress on creep behaviour (dynamic creep) has become of greater significance in recent years. The authors point out some of the variables which affect dynamic creep behaviour and present a detailed analysis of relevant published data. The review is based on a literature of twenty-four items, covering data on plain and low-alloy steels, lead, aluminium and representative high-temperature alloys of nickel-, cobalt- and iron-base types.

Elevated-Temperature Properties of Cast Iron

See abstract on p. 265.

Thermal-Shock Resistance of High-Temperature Alloys

F. K. LAMPSON, T. C. TSAREFF and A. W. F. GREEN: 'Thermal-Shock Testing, under Stress, of Certain High-Temperature Alloys.'
Proc. Amer. Soc. Testing Materials, 1957, vol. 57, pp. 965–76.

The authors report tests on eleven high-temperature wrought alloys, in sheet form: compositions are given in the table below. The tests were carried out by applying a known stress, heating the stressed material rapidly to a given temperature and cooling rapidly to temperatures of 100°–120°F. (38°–50°C.). Testing apparatus and technique are described and illustrated. Cycling was continued to failure, or if no failure had occurred after a given number of reversals, the test was stopped.

All the alloys tested showed excellent thermal-stress properties, especially at 1200° and 1350°F. (650° and 735°C.). In some cases a calculated stress corresponding to more than 90 per cent. of the short-time elevated-temperature tensile strength would be required to produce failure in approximately 100 cycles.

It was found that a direct relation exists between the stress calculated to produce failure in about 100 cycles in thermal shock and the short-time elevated-temperature tensile strength. The higher the tensile strength of any given alloy, the greater would be the stress required to produce failure under thermal-cycling conditions.

Metallographic examination of fracture surfaces (some of which are illustrated) indicated that in an austenitic high-temperature alloy, under the test conditions used, failure occurred by intergranular propagation.

Metallographic evidence is presented in support of a theory that preferential grain-boundary oxidation precedes tensile failure in applications which involve temperatures above 1200°F. (650°C.). Resistance to preferential grain-boundary oxidation is obviously a vital factor in determining the inherent long-term strength of any material for elevated-temperature use.

High-Temperature Testing of Metals

The 1958 *Report of the Joint A.S.T.M.-A.S.M.E. Committee on Effect of Temperature on the Properties of Metals* recommends the following test methods:

(1) 'Proposed Revised Tentative Recommended Practice for Short-Time Elevated-Temperature Tension Tests of Metallic Materials.'
Amer. Soc. Testing Materials, Preprint 68, June 1958, pp. 7–13.

(2) 'Proposed Tentative Recommended Practice for Conducting Creep and Time-for-Rupture Tension Tests of Materials.'
Ibid., pp. 14–26.

The two practices, which have been accepted by the Society for use pending adoption as standard, cover: apparatus and test specimens; control and measurement of temperature; measurement of strain, elongation and reduction in area; test procedure; method of reporting results. In the schedule relating to long-term testing, methods of plotting the data are also covered.

Factors Affecting Stress-Rupture of Threaded Test Specimens

H. T. MCHENRY and R. K. PITLER: 'Why Threaded Test Bars Lower 'A-286' Stress-Rupture Values.'
Iron Age, 1958, vol. 181, June 12, pp. 87–9.

The investigation reported in the two papers abstracted on p. 270 originated in the failure of

High-Temperature Sheet Materials used in Thermal-Shock Test

Alloy	C %	Si %	Mn %	S %	P %	Ni %	Cr %	Co %	Mo %	W %	Ti %	Nb %	Al %	Fe %	Other Elements %
'Tinidur'	0·07	0·75	0·92	0·007	0·012	26·00	14·70	—	—	—	1·90	—	0·62	Bal.	—
'A-286'	0·03	0·98	1·63	0·017	0·017	26·70	15·4	—	1·37	—	1·60	—	0·165	Bal.	0·29 V
'Discalloy 24'	0·05	0·85	1·41	—	—	25·60	13·70	—	4·40	—	2·30	—	0·55	Bal.	—
'19-9 DL'	0·29	0·80	0·91	0·018	0·016	9·70	20·00	—	1·50	1·63	0·30	0·48	—	Bal.	—
'Timken 16-25-6'	0·10	0·40	1·64	—	—	25·00	16·70	—	6·65	—	—	—	—	Bal.	0·13 N_2
'Haynes Stellite No. 88'	0·06	0·62	1·24	0·015	0·011	15·70	12·80	—	2·60	0·68	0·48	—	—	Bal.	—
'N-155'	0·07	0·54	1·15	—	—	20·20	20·90	20·60	4·00	2·78	—	0·88	—	Bal.	0·16 N_2
'S-590'	0·45	0·38	1·22	0·012	0·011	20·20	20·50	19·90	4·60	4·40	—	4·18	—	Bal.	—
'V-36'	0·30	0·20	1·03	0·011	0·010	20·60	24·80	Bal.	4·50	2·26	—	1·71	—	1·75	—
'WF-31'	0·15	0·62	1·39	—	—	9·50	20·20	Bal.	3·10	11·32	0·59	—	—	3·55	—
'L 605'	0·09	0·48	1·40	—	—	10·80	19·70	Bal.	—	16·0	—	—	—	1·95	—

threaded test specimens of 'A-286' austenitic heat-resisting steel to meet the stress-rupture requirements laid down in *S.A.E./A.M.S. Specification 7478* for bolts and screws intended for service at temperatures up to 1200°F. (650°C.). Smooth- and notched-bar rupture tests on the steel (a complex age-hardenable material containing 25 per cent. of nickel, 15 per cent. of chromium and small amounts of other elements) proved entirely satisfactory. To confirm whether the low rupture values obtained on threaded specimens could, as indicated by these results, be attributed to the geometry of the test piece, stress-rupture and tensile tests were carried out, at 1200°F. (650°C.) and room temperature, respectively, on smooth, notched and threaded specimens which had been subjected to the usual heat-treatment of one hour at 1800°F. (980°C.), oil-quenching, and re-heating for 16 hours at 1325°F. (718°C.).

The results led to the following conclusions:

(1) When the stress level is calculated from the mean of the root and pitch diameters, ultimate-tensile and yield-strength values are comparable for threaded and smooth-bar specimens.

(2) When the same calculation is applied to stress-rupture testing, rupture life for threaded specimens is shorter than for V-notch or smooth-bar specimens.

(3) If, in calculating the stress level of a threaded section, use is made of the root diameter to determine cross-sectional area, the rupture curve lies between those for smooth and for notched bars.

(4) The notch effect resulting from a thread is not as great as that from a standard V-notch specimen.

(5) Fine threads cause less notch effect than coarse threads.

Since threaded specimens do not appear to reflect true stress-rupture strength, it is recommended that standard test specimens should be used to evaluate the material.

See also

K. METCALFE: 'Solve Lamellar Phase Problem in 'A-286'.'

Iron Age, 1958, vol. 182, July 3, pp. 72–4.

Following investigation of the relationship between the geometry of a threaded specimen of 'A-286' stainless steel and its stress-rupture life (*see above*) the metallurgical factors involved in premature failure of such specimens are discussed.

It was found that failure to meet stress-rupture requirements was associated with formation of a lamellar precipitate (similar in appearance to pearlite) which appeared to originate at the grain boundaries, whence it advanced into the grains. The hardness in the precipitate regions was lower than in other areas. Formation of the phase was inhibited by addition of controlled amounts (over 0·001 per cent.) of boron, except where the steel was severely cold-worked (e.g., by thread-rolling) between solution-treatment and ageing: in the latter cases traces of the phase still appeared. (The type of cold work was significant, since cold drawing or tensile testing did not cause precipitation.)

It was found possible to produce a similar constituent by over-ageing the steel at 1450°F. (788°C.) and, on the basis of this finding, it is assumed that the deleterious lamellar phase was the result of an over-ageing effect caused by the combined influence of cold working and heat-treatment at the normal solution and ageing temperatures.

Two methods are proposed to prevent incidence of the phase or to eliminate such structure:

(1) Where the steel is not to be subjected to cold work, maintenance of the boron content at a level greater than 0·001 per cent. will be sufficient to prevent precipitation.

(2) Where the steel is to be severely cold-worked between solution-treatment and ageing, the phase can be eliminated and stress-rupture properties restored by solution-treating at 2000°F. (1093°C.), followed by normal ageing.

High-Temperature Fatigue-Testing Machine

D. J. DANEK and M. R. ACHTER: 'A High-Temperature, Vacuum and Controlled-Environment Fatigue Tester.'

Amer. Soc. Testing Materials, Preprint 73, 1958; 4 pp.

The apparatus described was developed in connexion with a study of the effect of gaseous and liquid environments on fatigue life of metals at elevated temperatures and high strain amplitudes (i.e., conditions which result in fatigue lives of less than 10^5 cycles).

Testing is carried out *in vacuo*, to provide a criterion by which the influence of other environments may be evaluated. The specimen is gripped in an upright position inside a cylindrical vacuum chamber, which is enclosed in a split-type resistance furnace. (The problem of transmitting motion through the vacuum-tight seal necessary for testing in controlled environments was solved by use of a magnetic coupling driven at the resonant frequency of the specimen.) The specimen is vibrated either by two oscillating permanent magnets outside the vacuum chamber or by two electromagnets which are excited alternately. The machine is automatically stopped (by means of a thyratron circuit) once a crack has developed in the specimen.

The paper contains full details of the construction and operation of the apparatus, and its use is demonstrated by results of fatigue tests on 18-8-Mo (A.I.S.I. Type 316) stainless steel at 1500°F. (815°C.) and in a vacuum of 3×10^{-5} mm. of mercury.

Since in vacuum fatigue no appreciable oxidation occurs, the equipment described can be used not only for studies of the influence of environment, but also for metallographic investigations of fatigue damage and crack initiation and propagation at elevated temperatures. A photomicrograph in the paper shows a typical crack in a failed specimen of austenitic steel, indicating the possibility of studying the 'surface rumpling' (probably substructure formation) which precedes cracking.

Calibration and Testing of Thermocouples

See abstract on p. 256.

Brazing Alloys for High-Temperature Service

M. D. BELLWARE: 'Fundamentals of Brazing for Elevated-Temperature Service.'

Welding Jnl., 1958, vol. 37, July, pp. 683–91.

The author points out that advances in the technology of brazing for high-temperature service has not been so rapid as the increase in demand for such techniques. The aim of his paper is therefore 'to foster a logical approach to the problems involved, by setting down some of the known facts and criteria which may be used to obtain predictable results.' To this end relevant information is reviewed and an attempt is made to establish some basic rules which will help the fabricator to produce satisfactory brazed joints. The definition 'high-temperature brazing' is considered as covering the range above 500°F. (260°C.).

After brief reference to the types of application for which high-temperature brazing is suitable, a critical review is made of the various groups of brazing alloy which have been developed to meet the needs of various sections of the high-temperature-engineering field. The properties, advantages and limitations of the following types of alloy are considered: silver-base alloys; copper-base alloys; manganese-, gold- and palladium-base alloys; nickel-base alloys. Typical compositions and properties are summarized for alloys of each group.

Particular attention is directed to the usefulness of nickel-base alloys for use at temperatures above about 1000°F. (540°C.). The functions of the respective elements added to nickel (chromium, silicon, boron, phosphorus, carbon) are considered with regard to their influence on properties which are significant in relation to brazing, and a general indication is given of the characteristics of nickel-phosphorus, nickel-silicon-boron, and nickel-chromium-silicon-boron-carbon alloys.

The importance of correct joint design and of control of inter-alloying is also urged, and the second part of the review is concerned with fundamental principles applicable to production of brazed joints, irrespective of the particular alloy used as the brazing medium. In this connexion the author calls attention to factors of primary importance in preparation for brazing, to methods of heating, and to means for reducing oxides (by use of special atmospheres, by vacuum brazing, by use of fluxes, by plating with a less-readily-oxidizable metal, or by pre-treatment by selective oxidation and pickling).

Some suggestions are made on lines for future research on brazing alloys, and it is emphasized that there is urgent need for a standard test for determination of the properties of such alloys, so that results obtained by various investigators may be satisfactorily correlated.

Effect of Nickel Undercoatings on Oxidation-Resistance of Enamelled Steel

See abstract on p. 261.

New Foundry for Production of Precision Castings

See abstract on p. 256.

Nickel-Aluminium Bronze: The 'Superston' Series

See abstract on p. 263.

Precipitation and Intercrystalline Corrosion in Niobium-Stabilized Chromium-Nickel Steel

K. BUNGARDT and G. LENNARTZ: 'Precipitation Phenomena in a Niobium-containing Austenitic Chromium-Nickel Stainless Steel, and its Relation to Intercrystalline Corrosion.'

Archiv f.d. Eisenhüttenwesen, 1958, vol. 29, June, pp. 359–64.

The work reported forms a continuation of that described by the same authors (*ibid.*, 1956, vol. 27, Feb., pp. 127–33), in which a study was made of precipitation reactions in a titanium-stabilized 18–10 chromium-nickel steel, as a function of time and temperature of heat-treatment and of the inherent susceptibility of the steel to intercrystalline corrosion. In the light of their findings, the authors were able adequately to interpret reports of failures in stabilized austenitic steels in terms of the chromium-impoverishment theory of intercrystalline corrosion. (The background to, and the salient features of, the investigation are summarized in *Nickel Bulletin*, 1956, vol. 29, No. 8–9, pp. 172–3.) The material used in this second investigation was a niobium-stabilized steel of the following composition: carbon 0·056, silicon 0·54, manganese 0·98, chromium 17·93, nickel 10·92, molybdenum 0·06, nitrogen 0·027, niobium 0·54, per cent. The study involved determination (by X-ray and analytical methods) of the solubility of the niobium-containing and other phases present, as a function of time and temperature of heat-treatment, and correlation of such observations with the results of intercrystalline-corrosion tests made on the steel after sensitization at various temperatures.

Specimens were heated for one hour at 900°, 1000°, 1100° or 1200°C., water-quenched, and then reheated as indicated below.

Time (hrs.)	Temperature °C.
20, 100, 500, 2,000 and 10,000 ..	500
5, 20, 100, 500 and 2,000	600
2, 5, 20,100 and 500	700
2, 5, 20, and 100	800

Susceptibility to intergranular corrosion was determined by means of the copper-sulphate/sulphuric-acid test.

Conclusions drawn from the test results are summarized below.

At temperatures above 900°C. the solubility of niobium carbide rapidly increased. Subsequent

annealing at a lower temperature caused the carbon which was thus taken into solution to precipitate as niobium carbide or chromium carbide. As the temperature fell rate of formation of chromium carbide became much more rapid than that of niobium carbide. Re-heating at 500°C. caused only slow precipitation of chromium carbide, and prolonged heating was required to induce sufficient precipitation at the grain boundaries to cause intergranular corrosion. It was noted, however, that the duration of treatment needed to cause such corrosion became shorter with rise in the quenching temperatures used.

Chromium-carbide precipitation reached a maximum at 600°C., at which temperature the diffusion rate of chromium was too slow to compensate for the loss of metal in the impoverished areas at the grain boundaries.

Chromium carbides were precipitated also at 700°C. when the steel had been previously quenched at 900°C. or at higher temperatures. Susceptibility to intergranular corrosion did not, however, occur, since the diffusion rate of the chromium was sufficiently high to prevent impoverishment. On heating for longer than 100 hours the chromium carbide began to break down somewhat, as the formation of niobium carbide became more rapid. Sigma phase occurred in the resultant chromium-rich zones.

The niobium formed compounds not only with the carbon but also with any nitrogen which had not been taken into solution. Since, in the steel examined, the niobium content was not sufficient to combine with all the nitrogen and carbon, chromium carbide precipitated on re-heating at 500° or 700°C., and at the former temperature the amounts precipitated were sufficient to cause intergranular corrosion.

The authors conclude that the combined results of the two investigations warrant the following findings in relation to the susceptibility of stabilized austenitic steels to intergranular failure:

(1) Nitrogen content plays an important rôle in determining the efficacy of the stabilizing element.

(2) Stabilizing additions present in proportions which should react completely with the nitrogen and carbon contents will not inhibit intercrystalline corrosion if solution-treatment has been such that much of the stabilizing element is taken into solution.

(3) When a steel is insufficiently stabilized, a tendency to intercrystalline corrosion is present after quenching from 900°C., but, in the case of the niobium-stabilized steel, only when it has been re-heated at 500°C.

(4) The presence of chromium-carbide precipitates is not a fully valid criterion of susceptibility to intercrystalline corrosion, since susceptibility is governed by the rate of diffusion of the chromium and the stabilizing element(s) at the sensitization temperature. The increase in solubility of the chromium carbide in the solid solution with rise in the temperature to which the steel is re-heated in the sensitizing range is also of significance.

(5) Even slight precipitation of chromium carbide is sufficient to sensitize the steel if the temperature involved is so low that the rate of diffusion of chromium is not sufficient to compensate for loss in the impoverished zone.

(6) As the time of holding at the temperature from which the steel is quenched is lengthened, the precipitation reactions in the sensitizing temperature region become slower, but there is no fundamental change in the mode of precipitation.

Resistance of Nickel Alloys to Corrosion by Caustic Alkalies

HENRY WIGGIN AND CO., LTD.: 'Wiggin Nickel Alloys *v.* Caustic Alkalies.'

Publn. 1529*, Aug. 1958; 51 pp.

The materials covered by the publication are 'Monel', 'K Monel', 'Inconel' and 'Nimonic 75', but for the purposes of the brochure the term 'Nickel Alloys' is extended to include also the 'A' and 'AT' grades of nickel. The extensive corrosion data presented (derived from tests under both experimental and service conditions) relate mainly to these materials, but information on the corrosion-resistance of steels and other alloys is included as a basis for comparison.

The publication falls into six sections. The first four discuss the behaviour of the nickel alloys in contact, at various temperatures and for various times, with caustic-soda solutions in the following concentration ranges: less than 30, 30–55, 55–75 and greater than 75 per cent. The fifth section is concerned with resistance to aqueous solutions of the weak-acid salts of sodium and potassium, which are alkaline in solution. The final section reviews industrial applications which involve exposure to caustic environments and for which experience has shown the high-nickel alloys to be eminently suitable. In this connexion the results of long-time corrosion tests under service conditions are discussed on the basis of experience in handling caustic in the caustic-soda and petroleum-refining industries, and in manufacturing rayon and other cellulose products, soap, pulp and paper.

Corrosion of Metals in Marine Tropical Atmospheres

C. R. SOUTHWELL, B. W. FORGESON and A. L. ALEXANDER: 'Corrosion of Metals in Tropical Environments. Part 2. Atmospheric Corrosion of Ten Structural Steels.'

U.S. Naval Research Laboratory, Washington, Report NRL 5002, Dec. 11, 1957; 16 pp.

An extensive investigation has been in progress since 1946, in the Panama Canal Zone, to study the corrosion rates and characteristics of fifty metals and alloys exposed to five tropical environments: marine and inland atmospheres, fresh-water immersion, and continuous and mean-tide sea-water conditions. The programme covers tests of sixteen

* *We shall be pleased to supply a free copy of this publication.*

years' duration, with inspection of specimens removed at intervals during that period. Ten identical panels of each material have been exposed in each location, to permit removal of two panels from each site after one, two, four, eight and sixteen years.

The eight-year specimens were removed in 1955. A report then prepared described the methods employed in the tests and gave particular attention to the corrosion behaviour of five metals: aluminium, lead, copper, zinc and nickel, and a structural steel (see *N.R.L. Report* 4929, June 19, 1957; abstract in *Nickel Bulletin*, 1958, vol. 31, No. 2, p. 59).

Reports by various investigators have demonstrated the increased resistance to atmospheric corrosion which is obtained by addition of small amounts of alloying elements to structural steels, a finding which is being utilized by steel producers throughout the world. The present report widens the scope of knowledge on this aspect by presenting results of the tests (eight-year period) of ten low-alloy steels exposed to the marine and inland tropical atmospheres of the Panama Canal Zone. Much detailed information (including barometric charts) is given, relating to weather conditions, constituents present in the atmosphere, etc., and other variables which would affect resistance to corrosion.

Of the ten structural steels considered, four were proprietary high-strength, low-alloy types (Cu-Ni, Cu-Cr-Si, Cu-Ni-Mn-Mo and Cr-Ni-Mn); one was a 2 per cent. nickel boiler steel; one was a 5 per cent. nickel steel; two were high-tensile chromium steels, and two were low-carbon steels, one of which was copper-bearing. Detailed compositions are given in the report, together with those of steels used by Larrabee in temperate-climate exposure tests, with which some comparisons are made (see *Corrosion*, 1953, vol. 9, pp. 259-71; *Nickel Bulletin*, 1953, vol. 26, No. 8-9, p. 160).

The results of observations made on the individual steels are presented in an extensive series of charts and tables. From these data, the following broad conclusions are drawn:

'Corrosion of the structural steels in the tropical marine atmosphere was from 1·5 to 2·2 times higher than in a temperate marine atmosphere. Comparison, on the mild steel, of the effects of the tropical marine and inland atmospheres showed that the marine conditions produced 1·7 times more corrosion weight-loss than the inland atmosphere.

'Tests on the same steel showed no difference, in either atmosphere, in type or extent of corrosion between pickled and mill-scale surfaces.

'Copper-bearing steel proved less effective in retarding corrosion in the tropical atmospheres than it has been found to be in temperate atmospheres: the corrosion of the copper-bearing steel, in the two tropical atmospheres, was, respectively, only 13 per cent. and 14 per cent. less than that of unalloyed mild steel.

'The 2 per cent. and 5 per cent. nickel steels were very effective in resisting corrosion: after the eight-year exposure the nickel steels were corroded 45-59 per cent. less than the copper-bearing steel. The 2 per cent. nickel steel was almost as effectively corrosion-resistant as the higher-alloy type.

'The corrosion-resistance of the chromium steel was broadly comparable to that of nickel steels. The 5 per cent. chromium type proved slightly superior in the marine atmosphere and appreciably better in the inland location: the 3 per cent. chromium steel gave slightly better results than the nickel steels in the inland atmosphere, but was inferior to them at the marine site.

'The four proprietary low-alloy steels displayed generally good resistance to tropical atmospheric corrosion; weight-loss in the eight-year period was 36-49 per cent. less than that of the copper-bearing steel. Variation in behaviour in this group was so slight that no individual ranking could be assigned.'

Effect of Chemical Cleaning on Stainless-Steel Condenser Tubes

J. P. ENGLE, C. F. REICH and A. C. SHOULTS: 'Effect of Velocity of Acid Water on Condenser Tube Corrosion.'

Proc. Engineering Soc., West Pennsylvania, 18th Annual Water Conference, Pittsburgh, Oct. 1957; 8 pp.

Impurities frequently present in water used as a coolant for heat exchangers cause formation of deposits on the surface of the tubes. The resultant loss of efficiency, the degree of which depends upon the thickness and type of the deposit, necessitates periodic cleaning, which may be effected by mechanical or by chemical means. The investigation reported in this paper was carried out to determine whether chemical cleaning would have a deleterious effect on the corrosion-resistance of the tubes: this effect was assessed by measurement of loss in weight caused by circulating an acidic cleansing solution through tubes made from typical materials of construction. Circulation was controlled in such a manner as to minimize extraneous effects which could be caused by cavitation, aeration, etc.

The solvent (a 5 wt. per cent. solution of inhibited hydrochloric acid in water) was circulated for 6 hours, at velocities of 2, 4, 6, 8 and 10 ft./sec. (0·6, 1·2, 1·8 and 2·4 m./sec.), through 12-in. (30-cm.) long tubes of six types of heat-exchanger tubing: copper, Admiralty brass, 'Muntz metal'; 0·13 per cent. carbon steel; molybdenum-containing and titanium-stabilized 18-8-types of chromium-nickel stainless steels (A.I.S.I. Types 316 and 321). The experiments were carried out at 150°F. (66°C.), and, for comparison, tubular specimens were exposed also under static conditions for the same time and at the same temperature.

Corrosion rates under turbulent-flow conditions were found to be higher than under static conditions. Rates for the copper-alloy specimens were not significantly greater at the higher velocities used than at 2 ft./sec. At 2 ft./sec. the carbon and stainless steels exhibited approximately the same increase (*vis-à-vis* static corrosion) in corrosion as the copper alloys, but at higher velocities rate of attack of the

steels slightly increased: the extent appeared to be a linear function of velocity.

The maximum corrosion rate for any of the materials tested (that recorded for the carbon steel) was equivalent to penetration of 0·000035 in./hr. (0·0009 mm./hr.), which is considered negligible. The authors therefore conclude that heat-exchange equipment constructed in the materials studied may safely be cleaned by circulating hot inhibited-hydrochloric-acid solutions: the resulting metal loss will be less than might be expected to occur during operational periods.

Mechanical Properties of 90-10 Copper-Nickel Alloys

See abstract on p. 264.

Nitriding of Stainless Steels

R. N. LIBSCH: 'Harder Stainless Practical.'

Steel, 1958, vol. 142, June 30, pp. 85–6.

The adherent chromium-oxide film present on stainless steels, from which they derive their high corrosion-resistance, constitutes a major difficulty in surface treatment of such steels, for example, by nitriding. Various methods of activating the surface prior to nitriding have been proposed, but some have proved uneconomical and/or of doubtful efficiency. This article discusses a salt-bath treatment, developed by American Bosch Arma Corporation, which is claimed to destroy the oxide film on an 18–8 chromium-nickel steel in 15 minutes. The steel can then be effectively case-hardened by normal nitriding procedure.

The components are immersed in the solution (about 60 per cent. sodium cyanide and 40 per cent. potassium cyanide), rinsed in water, and then placed in the nitrogen atmosphere. The depth of the hardened case obtained varies with time of treatment. The process is stated to be applicable to all the stainless steels: e.g., it is claimed to be possible, by this means, to increase the hardness of quenched-and-tempered martensitic and ferritic stainless steels to values considerably higher than those typical of surface-hardened conventional nitriding steels.

Nitrided austenitic steels are claimed to have increased fatigue-resistance and to maintain their hardness and oxidation-resistance up to a temperature of about 1000°F. (540°C.). While it is admitted that nitriding reduces the resistance of these steels to attack by certain corrosive media, it is suggested that where an application calls for abrasion-resistance allied with oxidation-resistance or non-magnetic properties, nitrided austenitic steels are eminently suitable.

Stainless Steel for Coal-, Coke-, and Ash-Handling Plant

W. JAKEMAN: 'Wear-Resisting Materials.'

Gas Jnl., 1958, vol. 293, Feb. 12, pp. 338–9.

The paper from which this excerpt is taken gives a short account of service tests carried out by the North Cheshire Group of the North Western Gas Board, to assess the suitability of materials which, it was thought, might with advantage replace mild steel in plant handling coal, coke and ashes. The main materials evaluated were 18–8 type chromium-nickel austenitic steel and an aluminium alloy, both used in sheet ¼-in. (6-mm.) thick. The mild steel was in sheet $\frac{3}{16}$ or ¼ in. (5 or 6 mm.) thick.

The materials were compared principally on the basis of economies achieved (i.e., it was required that the stainless steel or aluminium alloy should not only prove technically at least as suitable for the specific purpose as mild steel, but should also exhibit a service life, relative to that of mild steel, which would more than offset the higher capital costs involved). The advantages of the two materials are discussed in connexion with their use for skips and barrows for carrying coke; buckets of a gravity coal conveyor; dead plates on coke screens, and the screens themselves.

The paper also includes notes on the feasibility of using various ceramic materials, glass, stainless steel, cast basalt, cast iron and 'Meehanite' as linings for coal and coke chutes.

Typical of the savings cited for stainless steel are those achieved by its use in skips, which are expected to have a life of at least 2½ years (mild-steel skips wear out after six months), and the dead plates for coke screens, which, it is stated, will give a life six times as long as plates in mild steel. Attention is, however, drawn to the necessity for reinforcing the stainless-steel sheet in some way (for example, by welding on stainless-steel strips) to prevent flexing, which was found to accelerate wear.

Determination of Zinc in High-Nickel Alloys

See abstract on p. 264.

Influence of Phosphorus in Austenitic Manganese-(Nickel)-Steel Weld Metals

W. T. DELONG, W. L. LUTES and H. F. REID: 'Rôle of Phosphorus in Austenitic Manganese Weld Metal.' *Welding Jnl.*, 1958, vol. 37, July, pp. 316S–19S.

Results of an earlier investigation of typical manganese-nickel-steel electrodes had shown considerable variation in the mechanical properties of the resulting welds (*ibid.*, 1956, vol. 35, pp. 776–83; *Nickel Bulletin*, 1956, vol. 29, No. 10–11, p. 200). Analysis of the weld deposits, reproduced in the present paper, showed variations in the proportions of the major alloying elements present, but the differences appeared inadequate to explain the marked differences in tensile strength, elongation, impact strength and crack-resistance. It was noted that the phosphorus content of the weld metal which gave the best results was less than half that of the deposits which had less satisfactory properties. An investigation of the influence of that element was therefore undertaken, and the results are reported in the present paper. Experimental electrodes used were of the following type: carbon 0·75, silicon 0·65, chromium 0·38, manganese 14·5, nickel 3·46, per cent., with phosphorus varied between 0·01 and 0·06 per cent.

The results reported demonstrate that the phosphorus content of austenitic manganese-steel electrodes is a more potent factor than had previously been recognized. Minor increases in phosphorus content caused important deterioration in the properties of the weld deposits but nickel-manganese-steel weld metal with phosphorus in the range 0·01–0·02 per cent. showed outstanding tensile strength, ductility and crack-resistance. Phosphorus of the order of 0·035 per cent. appeared to be the maximum which could be tolerated without serious impairment of properties. Exploratory work on molybdenum-manganese-steel weld deposits confirmed these conclusions.

PATENTS

Recovery of Nickel from Lateritic Ores

Lateritic ores are subjected to a reducing roast and then mixed with an aqueous ammoniacal ammonium-carbonate solution (NH_3 8–28, CO_3 7–27, per cent.) in amounts sufficient to moisten it but not to cause caking. The iron present in the moistened ore is oxidized in contact with a gas containing 0·5–40 per cent. of oxygen and 30–99·5 per cent. of ammonia, and the treated ore is washed in an aqueous solution (consisting of NH_3 8–20, CO_3 7–22) to form a thin slurry, which, after a magnetizing treatment, is allowed to settle. The solution, which contains the nickel and any cobalt which may be present, is finally decanted off.

The process is claimed to reduce the nickel content of the ore to proportions sufficiently low as to make the ore suitable as a source of iron for steels in which a low nickel content is specifically required.

A. N. HIXSON and C. B. BARE, assignors to BETHLEHEM STEEL CO. *U.S. Pat.* 2,829,963.

Sulphurization of Nickel-Copper Matte in Extraction of Nickel

In the recovery of metals from scrap the melt is sulphurized by addition of finely dispersed elementary sulphur, introduced, either by means of a carrier gas or in vapour form, through the nozzles of the converter containing the melt.

An example describes the application of the process to a nickel-copper melt. The resultant mass may be treated with carbon monoxide, to form nickel carbonyl.

BADISCHE ANILIN- UND SODA-FABRIK A.G. *Brit. Pat.* 797,493.

Electrorefining of Nickel: New Inco Process

The claims of the patent are identical with those of *Canadian Patent* 556,649 (see *Nickel Bulletin*, 1958, vol. 31, No. 7, p. 201).

See also *ibid.*, 1958, vol. 31, No. 6, p. 155.

L. S. RENZONI and W. V. BARKER, assignors to INTERNATIONAL NICKEL CO., INC. *U.S. Pat.* 2,839,461.

Production of Nickel Strip by Direct Rolling of Powder

Carbonyl-nickel or carbonyl-iron powders may, by adjustment of the conditions of decomposition, be produced either as discrete particles, more or less round in shape, or as particles having a fibrous structure. It has been found that while use of powder of the latter type for sintered strip has the beneficial effect of increasing its strength in the compacted green form, the thickness of such strip is limited by the inability of the fibrous powder to flow uniformly to the gap between small rolls. This difficulty is overcome by forming the strip from a mixture of both powders: the amount of discrete particles present is accurately controlled to the degree required to ensure uniform flow of the strip to the gap (the limits stipulated are 25–95 per cent. of the total). The thickness of the compacted strip covered by the patent is 0·1–0·25 mm. and the diameters of the rolls should be in the range 50–100 mm.

A mixture recommended for nickel strip consists of the powders in equal proportions. For carbonyl-iron strip a mixture of 70 per cent. fibrous to 30 per cent. discrete particles is considered specially suitable.

MOND NICKEL CO., LTD. (inventors, H. EVANS and D. K. WORN). *Brit. Pat.* 796,220.
Similar to *Austrian* „ 195,649,
Belgian „ 549,614,
French „ 1,155,003,
Italian „ 557,002.

Production of Positive Plates for Nickel-Cadmium Batteries

A porous sintered nickel plaque is impregnated with nickel hydroxide by a process involving the following stages: (1) immersion in molten $Ni(NO_3)_2 \cdot 6H_2O$, at 85°–115°C. (preferably under reduced pressure); (2) decomposition of the nickel nitrate, by roasting the plaque for at least 10 minutes at 180°–250°C., into a product intermediate between the nitrate and hydroxide; (3) conversion of the intermediate product to nickel hydroxide by immersion for at least 1 hour in an aqueous solution of potassium hydroxide at 75°–85°C., and finally washing and drying.

The impregnation procedure is repeated twice, but a single impregnation cycle is claimed to produce plates having capacities which compare favourably with those of plates made by the conventional electrolytic procedure, involving four impregnation cycles.

P. L. BOURGAULT, P. E. LAKE and E. J. CASEY, assignors to MINISTER OF NATIONAL DEFENCE, CANADA. *U.S. Pat.* 2,831,044.

Nickel Cores for Oxide Cathodes

The oxide cathode claimed comprises a nickel core coated with an alkaline-earth emissive material and containing aluminium and/or magnesium and/or tungsten, which act as activating agents and also reduce the resistance of the interface between

the nickel and the oxide coating. The distribution of the impurities in the core is so arranged as to ensure that during the operating time of the cathode the interface layer is permeated at a constant rate: as a result the interface resistance remains satisfactorily low throughout. The necessary dispersal is achieved by fabricating the core from components containing the required concentrations of impurities.

STANDARD TELEPHONES AND CABLES, LTD.
Brit. Pat. 797,095.

Low-Temperature Self-Controlling Electric-Heating Elements

Elements suitable for electric blankets and other low-temperature heating devices comprise a centre cord of non-conducting material, such as rayon, cotton or glass, round which is wound a spiral of nickel resistance wire (99-100 per cent. purity), sheathed with P.V.C. plastic. By selection of the appropriate thickness and length of nickel wire (and provided that the thickness is sufficient to carry the required amperage) it is possible to manufacture elements for any maximum temperature.

T. A. KILY. *Brit. Pat.* 797,086.

Nickel in Cutting Tools

Cutting discs covered by the patent consist of diamond dust dispersed in a tungsten-carbide/nickel/cobalt matrix: the design embodies circular metal discs to which are brazed an annular array of cutting segments. Their advantage lies in the ability effectively to cut (with the same segments) not only all kinds of hard materials, irrespective of hardness, but also those which are very soft (and which previously would have necessitated a change of cutting segment). The cutting segments are made by pressing, at 1400°-1650°C., two powder mixtures consisting of 35-65 per cent. of tungsten carbide, the remainder nickel and/or cobalt, one of which, comprising the cutting edge of the segment, contains an addition of 2-6·5 per cent. of diamond dust.

The patent includes drawings which illustrate the design of the cutting discs.

CONSOLIDATED DIAMOND TOOL CORPN. (inventors, H. SCHWARZKOPF and J. G. VAN OTTERLOO).
Brit. Pat. 796,832.

Bonding of Nickel to Nickel

Metallic components having a melting point above 1400°C. are bonded together by depositing, electrolytically or by chemical reduction, a coating of cobalt- or nickel-phosphide on one or both of the components in the area where they are to be joined, and then heating the components (in appropriate contact with each other) at 800°-1400°C., so that the coating melts, the phosphorus is driven off and the nickel or cobalt wets the joint and forms a permanent bond The phosphorus content of the phosphide should be less than 15 per cent., and the components should be heated in a protective atmosphere (preferably hydrogen).

The process is particularly suited to bonding together nickel components for cathode tubes, where welding and brazing have proved unsatisfactory.

D. C. ANTEL, H. E. RICKS and A. P. COLAICO, assignors to WESTINGHOUSE ELECTRIC CORPN.
Canad. Pat. 558,108.

Electropolishing of Nickel and Nickel Alloys

The electrolytes to which the patent relates are claimed to facilitate electropolishing of nickel and non-ferrous nickel alloys at room temperature. The solutions consist essentially of sulphuric acid 5-66, hydrochloric 5-60, and water less than 75, vol. per cent. They require little or no temperature control, form no appreciable films or oxide coatings on polished parts, have a broad range of anode current densities, and have a highly efficient levelling action. Ternary diagrams are used to illustrate specific electropolishing solutions and conditions within the scope of the invention.

E. B. SAUBESTRE and E. R. BOWERMAN, assignors to SYLVANIA ELECTRIC PRODUCTS, INC.
U.S. Pat. 2,829,098.

Regeneration of Poisoned Nickel Catalysts

Nickel, copper, cobalt or iron catalysts which, during catalytic hydrogenation or dehydrogenation, have been poisoned by metallic sulphides, are restored to the active condition by treatment with liquid formic acid. The formic acid is passed over or through the catalyst in a current of an inert carrier gas (or in a static atmosphere of similar type). The flow of formic acid is then discontinued, and excess acid, together with the hydrogen sulphide formed by decomposition of the metallic sulphide, is driven off by the passage of an inert gas or hydrogen. It is emphasized that the formic acid must be maintained in the liquid state: treatment by the acid in the vapour phase is less effective.

E. B. MAXTED. *Brit. Pat.* 797,111.

Nickel-Alumina Powder Mixtures

Substances containing a high proportion of powdered metals, metal oxides, carbides, silicides, borides, or other hard metal compounds are rendered sufficiently plastic to be worked (e.g., extruded), by addition of finely powdered Al_2O_3 of low bulk density and an aqueous solution of colloidal alumina (alumina gel). One of the examples cited relates to a mixture of three parts of nickel powder, three parts of Al_2O_3 and 3 parts of 40 per cent. alumina-gel solution. The dried, shaped article contained 58·3 per cent. of nickel and 41·7 per cent. of Al_2O_3.

SIEMENS-PLANIAWERKE A.G. FÜR KOHLEFABRIKATE.
Brit. Pat. 800,375.
Similar to *French* „ 1,138,916.

Additives for Increasing Oxidation-Resistance of Lubricating Oils

The oxidation-resistance of transformer, switch and turbine mineral lubricating oils is increased by addition, in combination, of two classes of material which were previously used only singly for this purpose: (*a*) a secondary aromatic mono-, di- or polyamine in which the nitrogen is attached directly to two aromatic radicals, and (*b*) an oil-soluble metal or metalloid salt of an organic dithiocarbamic acid. Preferred materials are listed: those pertaining to group (*b*) are salts of zinc, cadmium, nickel, cobalt, arsenic, bismuth or selenium. The additives may be introduced into the oil base in amounts ranging from 0·01 to 1 wt. per cent.: they are preferably used in equal proportions.

C. C. WAKEFIELD AND CO. LTD. (inventors, P. W. L. GOSSLING and E. R. DENNIS). *Brit. Pat.* 795,811.

Activation of Nickel prior to Chromium Plating

Nickel surfaces, as undercoats or as basis metal, are prepared for chromium plating by electrolytic activation in an aqueous solution of chromic acid (together with minor proportions of other ions such as sulphate, chloride, fluoride, silico-fluoride or fluosilicate ions, which are added as acids or as salts). The composition of the solution and the operating conditions used are given below. Preferred values are noted in brackets. The nickel surface forms the cathode and the anode may be of lead or lead alloy.

	oz./gal.	g./L.
Chromic acid	2-6	12·5-37·5
Sulphate	0·05-0·30 (0·10-0·15)	0·3-1·86 (0·6-0·9)
Temperature	60°-160°F. (80°-130°F.) 16°-71° (27°-54°C.)	
Current Density	2-12 (4-6) amp./sq. ft. 0·22-1·3 (0·43-0·65) amp./dm.²	

Duration of treatment 30 second-3 minutes

Optimum results are obtained with the range of electrolyzing times quoted but prolonged immersion (up to 30 minutes or more) has no deleterious effects on components; this improvement is the primary advantage claimed for the invention.

J. D. PATRICK, assignor to GENERAL MOTORS CORPN. *U.S. Pat.* 2,836,552.

Black-Nickel Plating

Adherent, uniform black deposits, having excellent physical properties, are made from a solution which permits appreciable latitude not only in concentrations of the constituents but also in plating variables, e.g., pH, current density and plating time. Such operating flexibility makes the process adaptable to production of any specific finish which may be required, and the economic drawbacks involved in strict control are eliminated.

Plating conditions and the composition of the plating solution are given in the next column (with preferred values in brackets).

	g./L.
$NiCl_2.6H_2O$	50–165 (60–90)
NH_4Cl	7·5–45 (15–30)
NaCNS	7·5–30 (10–20)
$ZnCl_2$	15–60 (20–50)

pH 2·3–5·5

Current density is related to concentration of $NiCl_2.6H_2O$.

The abrasion-resistance and adhesion of the deposit are greatly improved by subjecting the work to a preliminary treatment involving deposition of a nickel coating from an acid nickel-chloride solution (containing not more than about 350 g./L. of $NiCl_2.6H_2O$) at a pH of not more than 3. A preferred solution contains 150–240 g./L. of nickel chloride hexahydrate and 30–40 g./L. of hydrochloric acid. The solution is operated at 60°–80°F. (16°–27°C.) and at a pH in the range of 0–0·5.

The component is treated anodically for 1–3 minutes and then cathodically for 5–10 minutes, using current densities of 20–40 amp./sq. ft. (2·16–4·32 amp./dm.²).

W. A. WESLEY and B. B. KNAPP, assignors to INTERNATIONAL NICKEL CO., INC. *U.S. Pat.* 2,844,530.

Electroless Deposition of Nickel: Regeneration of Plating Solutions

An improved method for continuous deposition by the electroless process employs an aqueous plating solution containing (mole/litre): 0·15–0·30 of hypophosphite ions, 0·30 of lactic anions, 0·03 of propionic amons, and sufficient nickel cations to provide a ratio, *vis-à-vis* the hypophosphite ions, in the range 0·25–0·60. In continuous chemical nickel plating the solution, which is operated at a pH of between 4·5 and 4·8, is regenerated, as required, by progressive additions of hypophosphite, lactic, propionic and nickel ions in the ratio of 0·24 : 0·03 : 0·005 : 0·08 mole. The additions of lactic and propionic ions are so controlled as to ensure that the plating rate and the phosphite-anion tolerance are conducive to optimum nickel plating.

P. TALMEY and D. E. METHENY, assignors to GENERAL AMERICAN TRANSPORTATION CORPN. *U.S. Pat.* 2,837,445.

Acid-Type Solutions for Plating by Chemical Reduction

Aqueous chemical-reduction nickel-plating solutions fall within the following composition range (g./L.): a soluble nickel salt (e.g., chloride or acetate) 5–50, a hypophosphite reducing agent 5–100, a buffer (glycollic, lactic or acetic acid) 15–100, glue or gelatin 0·1–0·05. The solution is operated at a pH within the range 3–6·5 and at a temperature of 170°–200°F. (77°–93°C.). The nickel is usually deposited at a rate of 0·0005–0·0006 in. (0·0125–0·015 mm.) per hour.

Solutions of the composition quoted are claimed to have an improved stability and operating life. Addition of glue or gelatin confers greater corrosion-resistance and smoothness on the resultant deposit,

and, in this connexion, the patent also stipulates a final heat-treatment, for at least one hour at a temperature within the range 350°–800°F. (177°–427°C.), as a means of increasing ductility and corrosion-resistance.

E. L. BOLIN, assignor to GENERAL MOTORS CORPN. *U.S. Pat.* 2,836,510.

Brightening Agents for Use in Electrodeposition of Nickel

Nickel deposits of high ductility and brightness are obtained by addition, to a nickel-chloride or nickel-sulphate plating solution, of 0·001–1 g./L. of an acetylenic polyamine (the product of a reaction between an acetylenic compound and an alkylene polyamine), preferably in conjunction with an aromatic sulpho compound (taken from the class consisting of benzene, toluene and naphthalene, and containing from 1 to 3 sulphonic groups). The following polyamines are covered by the patent: diethylenetriamine, ethylenediamine, triethylenetetramine, tetraethylenepentamine and pentaethylenehexamine.

Examples are given illustrating the manufacture of the reaction products and referring to compositions (within the scope of the patent) which have proved effective.

F. I. NOBEL and B. D. OSTROW, assignors to ELECHEM CORPN. *U.S. Pat.* 2,836,549.

Organic sulphonic acids or their salts are added as brighteners to acid aqueous plating solutions of an inorganic salt of the metal to be deposited (nickel, copper or zinc). Structural formulae are given for the classes of brighteners claimed, and methods are outlined by which the compounds may be produced.

W. GUNDEL, H. HAAS and W. STRAUSS, assignors to DEHYDAG, DEUTSCHE HYDRIERWERKE G.m.b.H. *U.S. Pat.* 2,837,472.

Nickel-Plating of Sintered Iron and Steel

In order to facilitate plating of parts produced by powder-metallurgy techniques, porosity is eliminated by pickling the part, and bringing it into contact with an easily-fusible metal, so as to achieve a dense coating (about 0·015 mm. thick), which forms a suitable basis for subsequent nickel- or chromium-plating. The undercoating metals should alloy with the basis metal and they should preferably have a melting point below 425°C.: tin, cadmium, zinc, and their alloys with one another and/or with lead, antimony or bismuth are recommended for coating sintered iron and steel, with the plating of which the patent is mainly concerned. Treatment may be effected either by immersion in a molten bath of the fusible metal or alloy, or by coating with a mixture of flux and a powder of the easily fusible metal.

W. E. P. BAYLEY (communicated by HUSQVARNA VAPENFABRIKS A.B.). *Brit. Pat.* 796,128.

Nickel Plating of Ceramic Materials

A coating of nickel is produced on the extremities of ceramic resistance materials by heating their surface and passing them through a bath of liquid nickel carbonyl: the temperature of the component is maintained at a level which will cause decomposition of the carbonyl, with resulting deposition of a coating of nickel on the surface of the ceramic. The entrance to the vessel in which the reaction takes place is sealed, e.g., by refrigeration, and a water seal at the exit is used both to prevent exit of gas and to provide an initial rinsing system for the component. The nickel layer forms a suitable surface for soldering on the lead wires to ceramic resistors: this application is the main aim of the invention.

RESISTA FABRIK ELEKTRISCHER WIDERSTÄNDE G.m.b.H. *French Pat.* 1,156,065.

Application of Nickel + Copper Coatings to Ceramic Materials

The copper coatings which form the condenser electrodes of ceramic capacitors are bonded to the ceramic by means of two intermediate layers of nickel: both are of flash thickness, but the initial layer is deposited by gas-plating viâ nickel carbonyl, while the second is electrodeposited. The outer coating of copper is deposited electrolytically, to a thickness needed to obtain the required conductivity. The initial layer of nickel provides the adherence to the ceramic, but cannot be directly electroplated with copper; the second nickel layer provides a surface suitable for electrodeposition of this final coating.

The composite coating has electrical properties similar to those of a purely copper coating, and in addition is intimately bonded to the ceramic, so that full advantage can be taken of its dielectric constant.

J. W. SCHELL, assignor to ERIE RESISTOR CORPN. *Canad. Pat.* 556,952.

Coating of Metals with Bismuth-Nickel Alloys

The process described, which is suitable for the production of adherent bismuth-nickel coatings on metallic articles of various shapes (as required in certain atomic energy applications) involves three main stages:

(1) Electrodeposition of the desired thickness of nickel on the component, followed by electropolishing.

(2) Immersion of the nickel-plated component in a bismuth-plating solution, in which it is subjected to alternating cathodic and anodic treatment until the required thickness of bismuth is deposited. Stages (1) and (2) are then consecutively repeated to achieve a composite coating. (The article is immersed in hydrochloric acid after deposition of each layer of bismuth, to remove bismuth hydroxide formed during rinsing.)

(3) Alloying of the composite coating by diffusion heating, carried out at sub-atmospheric pressure, preferably at 90°C.

Details of the process are claimed for (and illustrated by a description of its application to) an aluminium object. Aluminium is the preferred basis metal, since, coated with the bismuth-nickel alloy which forms the neutron source, it may be used as a component in neutron reactors. The process is stated to be the only satisfactory means of coating curved surfaces with bismuth-nickel alloys.

J. G. BEACH, assignor to the UNITED STATES ATOMIC ENERGY COMMISSION. *U.S. Pat.* 2,821,505.

Nickel/Nickel-Carbide Coating of Electrodes of Thermionic Tubes for Reduction of Secondary Electron Emission

In an improved thermionic tube deleterious secondary electron emission from the surfaces of electrodes (e.g., copper) subject to electron bombardment is minimized by application, to the electrode, of a nickel-carbide coating over an underlayer of nickel.

The nickel-carbide/nickel coating is produced by cleaning the tube elements; flash-plating, to give a nickel deposit about 0·0005 in. (0·0125 mm.) thick; heating at 500°C. or higher, in a hydrogen atmosphere which has been bubbled through a hydrocarbon such as benzene, gasoline or kerosene; and finally immersing them in agitated distilled water, to remove excess carbon particles.

VARIAN ASSOCIATES. *Brit. Pat.* 796,046.

Production of Intricately-Shaped Metal Components by Gas Plating

Metal articles are produced by coating a blank of cellulosic material (preferably cardboard) of requisite shape with a heat-conductive film (preferably aluminium paint) and heating, *in vacuo*, to a temperature at which a gaseous metal compound will, on contact, decompose and deposit its metallic constituent on the film-covered blank. After thus coating to the desired thickness, the cardboard blank is burnt away to provide the finished article. The method is claimed to be particularly advantageous where the article is to include, as important constituents, high-melting-point metals such as tungsten or molybdenum, or has to be of intricate shape.

The plating gas may be any of the following: $Ni(CO)_4$, $Cr(CO)_6$, $Mo(CO)_6$, $W(CO)_6$ or $Cu(C_5H_7O_2)_2$. Nickel carbonyl is, however, recommended as most suitable for deposition, since it gives a fine corrosion-resisting finish which requires no further treatment.

By way of illustration, the patent includes details, supplemented by drawings, of articles (e.g., an angle iron, a spring and a network pattern) produced in accordance with the invention.

P. R. MARVIN, assignor to COMMONWEALTH ENGINEERING CO. OF OHIO. *U.S. Pat.* 2,834,690.

Cladding of Mild Steel with Titanium or Zirconium

Mild-steel plate is clad with zirconium or titanium by means of an intermediate bonding layer (of chromium, cobalt, molybdenum or silver) which precludes formation of brittle iron-titanium or iron-zirconium intermetallic compounds which would deleteriously affect adherence of the cladding to the basis metal. The chromium, cobalt or silver is electrodeposited onto the zirconium or titanium. Molybdenum is applied in the form of thin sheet. These layers are then over-plated with a coating of nickel (which forms a better diffusion bond with the mild steel). The three-layer composite, with the nickel surface in contact with the mild steel, is finally diffusion-welded at 1400°F. (760°C.), under pressure sufficient to achieve a reduction of one-half of the original thickness.

HORIZONS, INC. (inventor, F. C. WAGNER). *Brit. Pat.* 797,023.

Preparation of Iron or Steel for Enamelling

British Patent 674,490 covered a process for increasing adherence of porcelain enamel to iron or mild steel. The technique involved nickel plating the surface, heat-treating the article to form a scale, and finally pickling, to remove the scale before enamelling. The present patent modifies this process to the extent that the nickel deposit may be replaced by cobalt, mixtures of cobalt and nickel, or alloys with high cobalt and/or nickel content. Heat-treatment is for 2-5 minutes in an atmosphere of burnt natural gas containing 11 per cent. combustibles and having a dew point of 130°-180°F. (54°-83°C.) at 1400°-2000°F. (760°-1095°C.). The pickling solution is 6-25 per cent. sulphuric acid, used at 160°-190°F. (71°-88°C.). A decarburizing treatment (details of which are given) is recommended, and it is found advantageous to coat the basis metal, after pickling, with nickel, as a final step before enamelling.

ARMCO INTERNATIONAL CORPN. (inventors, F. G. SUTPHEN, J. J. CANFIELD, R. L. MYERS, J. E. SAMS and R. S. BURNS). *Brit. Pat.* 795,632. (Addition to „ „ 674,490.)

Production of Nickel-containing Alloys from Mixtures of Nickel and Other Amalgams

Alloys in the form of suspensions in mercury are produced (at temperatures well below their melting point) by heating mixtures of the appropriate amalgams to a temperature equal to or higher than that at which the most thermally stable of the compounds will dissociate. The process is described and claimed as applying to the use of mixtures of binary or ternary amalgams of nickel, iron, chromium, cobalt and other metals. Details are given of production procedures and of temperatures of dissociation.

SIEMENS UND HALSKE G.m.b.H. *Brit. Pat.* 796,805.

De-Gassing of Non-Ferrous Metals and Alloys

Dissolved gases are removed from molten non-ferrous metals and alloys using, as the flushing gas, nitrogen derived from a solid material. Calcium cyanamide is added to the melt, at a temperature preferably higher than 1100°C., in conjunction with

sufficient carbon to liberate, as gas, the nitrogen content of the cyanamide. The carbon may be contained (as an impurity of at least 15 per cent.) in the calcium cyanamide.

The process is suitable for de-gassing all non-ferrous metals and alloys which can be conveniently treated in the region of 1100°C.: it is applicable therefore to nickel and nickel-base alloys. Iron and steel do not come within the scope of the invention, because nitrogen is soluble to an appreciable extent in ferrous materials.

BRIT. OXYGEN CO., LTD. (inventor, J. A. CHARLES). *Brit. Pat.* 798,755.

Magnetostrictive Nickel-Cobalt Alloys

The claims of the patent referred to below are similar to those of *Brit. Pat.* 774,727 (see *Nickel Bulletin*, 1957, vol. 30, No. 7-8, p. 148).

C. A. CLARK, assignor to INTERNATIONAL NICKEL CO., INC. *U.S. Pat.* 2,836,492.

Nickel-base Alloy for Use in Cathode Cores

The core of the cathode, which is coated with an emissive layer of alkaline-earth oxides, is of the following base composition: chromium 1, tungsten 2, cobalt 0·5, aluminium 0·04, per cent., remainder nickel. Minor amounts of the following elements may also be present: manganese, iron, carbon, copper, silicon. Inclusion of chromium in the alloy results in improved life and emissive characteristics, reduces sublimation of the core material, and increases its rigidity.

D. R. KERSTETTER, assignor to SYLVANIA ELECTRIC PRODUCTS, INC. *U.S. Pat.* 2,837,423.

Tungsten-Zirconium-Nickel Alloys

The addition of small amounts of zirconium (0·05-1·5 wt. per cent.) and tungsten (1-5 wt. per cent.) to nickel alloys normally used in indirectly-heated cathodes (e.g., for sleeves or cups) is claimed to enhance the hot strength of the material at operating temperatures, whilst at least maintaining the good emission and sublimation characteristics of the original alloy.

Compositional limits are given as follows: zirconium 0·05-1·5, tungsten 1-5, magnesium 0·07 max. and/or aluminium 0·1 max., per cent., balance nickel, with silicon $\geq$ 0·02, iron $\geq$ 0·1, manganese $\geq$ 0·1, carbon $\geq$ 0·08, copper $\geq$ 0·05, per cent.

R. L. HOFF and A. M. BOUNDS, assignors to SUPERIOR TUBE CO. *U.S. Pat.* 2,833,647.

Nickel-Tungsten-Aluminium Cathode Alloy

A cathode alloy claimed to have thermionic emissive properties at least as good as those of commercial nickel-base cathode material, and superior high-temperature strength, falls within the following percentage limits: nickel 68-94·5, tungsten 5-30, aluminium 0·05-2. The alloys are vacuum melted from high-purity metals, to minimize the effect, on workability, of their high tungsten content.

L. W. KATES, assignor to SYLVANIA ELECTRIC PRODUCTS, INC. *Canad. Pat.* 557,441.

Nickel-Rhenium-Alloy Cores for Vacuum-Tube Cathodes

The electrically conductive core of a thermionically active cathode of the alkaline-earth-oxide type consists of a nickel-base binary alloy containing 1-30 wt. per cent. of rhenium. The core should have a factor of merit greater than 1·3 and a collapsing temperature of between 840° and 915°C. when the rhenium content is between 1 and 10 per cent.; at contents greater than 10 per cent. the collapsing temperature should be above 915°C.

Such cores are claimed to be characterized by the following advantages: ease of preparation; stability at the temperatures of manufacture and use; effective reduction of the alkaline-earth oxides; speed of diffusion, without formation of interface layers due to the volatility of the reaction products; improved mechanical properties; higher fusion and recrystallization temperatures; complete de-gassing; reduced thermal conductivity; increased electrical resistivity.

ETABS. CHARLES BERTOLUS. *Brit. Pat.* 797,998. Similar to *French* „ 1,117,317.

Production of Cathodes for Thermionic Valves

The emissive portion of a thermionic cathode is produced by sintering a compact formed from a mixture of the following materials: powdered alkaline-earth-metal carbonates (10-50 wt. per cent.), powdered nickel and/or cobalt (preferably 70 wt. per cent.), and a powdered alloy comprising nickel (and/or cobalt) and at least one reducing agent. The carbonates should include at least 10 mol. per cent. of barium carbonate, and the proportion of the reducing agent(s) is such that there are at least 2·5 atoms of barium to each atom of reducing agent. The powdered alloy preferably consists of nickel 70, silicon 30, wt. per cent. (a typical composition is given as 70 wt. per cent. of a mixture consisting of barium carbonate 49·5, strontium carbonate 43·5, calcium carbonate 7, mol. per cent.; 0·35 wt. per cent. of the nickel-silicon alloy; and 70 wt. per cent. of carbonyl nickel).

The mixture is pressed into one end of the metal tube of the cathode to form a disc-shaped compact, which is sintered (to decompose the carbonates and produce the corresponding oxides) after installation of the cathode assembly in the valve, and while the valve is being evacuated. Alloying the reducing agent with nickel or cobalt ensures avoidance of excessive oxidation during decomposition of the carbonates. This effect is the main advantage claimed for the invention, since it enables the reducing agent to retain sufficient activity to reduce the barium

oxide and so produce enough free barium for efficient emission.

M–O VALVE CO., LTD. (inventors, I. BRODIE, J. T. A. HARVEY, K. JACKSON and R. O. JENKINS).
Brit. Pat. 797,762.

See also following abstract:

In a later patent the process claimed in *Brit. Pat.* 797,762 is applied to electric-discharge devices other than thermionic valves. The invention is described with reference to the manufacture of a thermionic cathode for a cathode-ray tube.

GENERAL ELECTRIC CO., LTD. (inventors, I. BRODIE, J. T. A. HARVEY, K. JACKSON and R. O. JENKINS).
Brit. Pat. 797,842.

Sintered Copper-base Bearing Alloys

Use of porous-metal bearings has, in some applications, been limited by poor resistance to wear. According to this patent bearing alloys of high wear-resistance and having excellent oil-retaining properties are produced by sintering a powder mixture consisting of 0·25–15 per cent. alumina, 2–15 per cent. nickel, remainder (at least 50 per cent.) copper or copper-base alloy, to achieve a fine dispersion of the Al_2O_3 throughout the alloy. In addition to nickel, the following may be present: carbon 0·3–6·5, tin up to 18, aluminium 2–11, per cent.

Compacting and sintering procedures are described. Solution and ageing heat-treatments are recommended if a considerable amount of nickel is included in the powder mixture.

R. F. THOMSON, assignor to GENERAL MOTORS CORPN.
U.S. Pat. 2,831,243.

Selenium-containing Nickel-Copper-Manganese-(Cobalt) Alloys for Watch Parts

Copper-nickel-manganese alloys have the non-rusting and non-magnetic properties required for fine components of watches, e.g., pallets and balance wheels, but are limited by poor machining qualities. According to the patent, this disability is removed by making such parts from copper-nickel-manganese alloys to which selenium is added and, optionally, cobalt. Compositional limits are given below (preferred percentages are in brackets).

Ni	Cu	Mn	Co	Se
30–34 (32)	30–34 (32)	30–34 (32)	1–8 (3·5)	0·01–4 (0·5)

A Vickers hardness of about 500 can be achieved by annealing the alloy within the range 700°–1000°C., quenching, cold working and tempering at 300°–500°C.

INSTITUT DR. ING. REINHARD STRAUMANN A.G.
Brit. Pat. 796,429.

Nickel-containing Addition Alloy for Production of Sterling Silver

A white, ductile sterling silver, which is non-tarnishing and highly resistant to oxidation, is produced by addition, to pure silver, of an alloy of the following composition: zinc 65–75, copper 20–30, nickel 5, per cent. The addition alloy is in the proportion 7·3 per cent. to 92·7 per cent. silver.

J. S. SHEFF. *Canad. Pat.* 556,831.

Removal of Superficial Oxide Films from Nickel-Cobalt-Iron Components of Glass-to-Metal-Sealed Articles

To achieve an effective seal between glass and alloys containing nickel 24–34, cobalt 5–25, per cent., remainder iron (e.g., 'Kovar') it is necessary first heavily to oxidize the surface of the alloys. This surface film is retained on the composite article, and prevents deposition, on the alloy surface, of corrosion-resisting coatings necessary for many applications. Safe removal of the oxide film without attack on the underlying alloy (a vital factor in view of the critical dimensional tolerances frequently required in glass/metal composites) is the main aim of the invention.

The oxidized article is immersed in a hot aqueous solution of sulphuric acid containing at least 75 g. of ammonium sulphate per 100 ml. of acid. The oxide film is, in general, completely removed after 3–5 minutes' immersion, but articles left in the solution for 45 minutes have shown no signs of attack on the underlying alloy.

PHILCO CORPN. *Brit. Pat.* 795,980.

Method of Promoting the Flow of Molten Metals

The spread of molten metal (e.g., in brazing) is promoted by applying a suspension of finely powdered metal to the surface of the basis material; the molten metal is then applied in an environment which precludes the formation of oxides or nitrides. The metal powders (nickel, cobalt or iron powders are preferred materials) should have a melting point lower than that of the basis metal, while that of the molten metal should be lowest of all three. The basis and powder metals should be wettable by the molten materials; the flow of the latter over the metal-powder coating is then facilitated by the capillary attraction of the numerous small inter-particle voids.

The basis metals and alloys to which the invention is applicable include tungsten, and tungsten-silver and tungsten-copper-nickel alloys; iron; steel; cobalt; nickel, nickel-iron, nickel-iron-cobalt and nickel-copper alloys; molybdenum and alloys of molybdenum with silver, copper or nickel; and chromium-bearing alloys. Silver, copper, the silver-copper eutectic, lead, tin or lead-tin alloys are the preferred molten materials and nickel and nickel-copper alloys have also proved suitable.

Claims are made for the following applications of the process: production of pre-flowed brazes on

components preparatory to furnace brazing; brazing without the need for pre-wetting; elimination of surface porosity; torch-brazing molybdenum without a flux; decorative finishing; brazing of tungsten-carbide tips to tools; production of electrical contacts *in situ*.

ENGLISH ELECTRIC CO., LTD. (inventor, A. J. WOOD). *Brit. Pat.* 796,682.

Brazing of Corundum Windows to Nickel-Iron-Alloy Components

Corundum offers properties (low dielectric loss, refractoriness, and resistance to thermal shock) which would make it an ideal material for window seals, but its coefficient of thermal expansion differs along two axes and it cannot therefore be sealed directly to the metal aperture. According to this patent, the problem is solved by bonding, to the edges of the corundum window, a metallic coating which then provides the means by which the disc is sealed (by brazing, soldering or other suitable techniques) to the body of the component. The latter is made from a nickel-iron alloy (containing 43 per cent. of nickel and 57 per cent. of iron) which has a coefficient of thermal expansion similar to that of the corundum. The window is metallized for brazing by sintering onto its edge an 80–20 mixture of molybdenum and manganese powders and finally superimposing a nickel flash. A 70–30 copper-silver alloy is the preferred brazing medium.

GENERAL ELECTRIC CO., LTD. (inventors R. B. DYOTT and D. E. P. JENKINS). *Brit. Pat.* 796,883.

See also following abstract:

The materials and sealing process described in British Patent 796,883 are used to manufacture the corundum window in the envelope of the thermionic valve claimed in this associated patent.

M–O VALVE CO., LTD. (inventors, R. B. DYOTT and D. E. P. JENKINS). *Brit. Pat.* 796,884.

Use of Gaseous Metal Carbonyls as Alloying Agents in the Production of Steels

In the production of alloys or alloy steels the alloying constituents are introduced into the melt in the form of the appropriate gaseous metal carbonyls. The carbonyl decomposes and releases the metal, and the resultant waste carbon monoxide is burned at the mouth of the cupola or furnace. The process is claimed as a means of making a stainless steel containing 12–22 per cent. chromium and 10–21 per cent. nickel. After introduction of the carbonyl the steel is treated with a deoxidizer.

The process (furnace and equipment for which are described) is stated to have the advantage, over conventional scrap-addition methods, of rapidly and completely diffusing the alloying elements throughout the melt, which contributes to the production of a material with uniform characteristics.

F. E. DRUMMOND, assignor to COMMONWEALTH ENGINEERING CO. OF OHIO. *U.S. Pat.* 2,826,494.

Sintered Electrodes for Spark Machining

Electrodes for spark machining are produced by sintering, at a temperature below 1600°C. (preferably at 1500°C.), a mixture of powders consisting of 70–95 per cent. of one or more refractory metals or their carbides and 5–30 per cent. of one or more metals or alloys the melting point of which is below the sintering temperature, and which are capable of dissolving (and therefore binding together) the refractory constituents. Tungsten and molybdenum are claimed as suitable refractory metals; iron, nickel, copper and cobalt or their alloys as binding materials. A typical composition comprises tungsten 90, nickel 7, copper 3, per cent.

The electrodes have a homogeneous and isotropic structure and in operation wear uniformly without cracking. They are readily machined and can be produced in a variety of forms, at much lower temperatures than those needed for the manufacture of other refractory electrodes.

STE. D'ELECTRO-CHIMIE, D'ELECTRO-METALLURGIE ET DES ACIERIES ELECTRIQUES D'UGINE. *Brit. Pat.* 797,719.

Matrix-Hardened Creep-Resistant Alloy

The heat-resisting matrix-hardened alloy of the invention consists essentially of 5–30 per cent. of chromium, up to 25 per cent. of iron, and up to 90 per cent. of nickel and/or up to 70 per cent. of cobalt (to a combined total, if both nickel and cobalt are present, of at least 40, preferably 50, per cent.). The alloy is hardened by a random dispersion, throughout the matrix (at distances of less than 1 micron) of a slip- and recovery-inhibiting phase consisting of the carbides, borides, silicides and nitrides of titanium, zirconium, niobium, tantalum, hafnium and vanadium, and also the disilicides of molybdenum and tungsten. The heat-resisting material is produced by powder-metallurgical methods. The hardening compound and matrix alloy, in particle sizes of less than 10 and 40 microns, respectively, are compacted under a pressure of 30–150 t.s.i. (47–236 kg./mm.^{2}), and sintered, preferably in two stages, at a temperature above 1100°C. and below the point of incipient fusion. Compacting pressure is <100, preferably <50, microns. Finally, to eliminate porosity, the sintered article is hot-worked to a reduction of at least 50 (preferably 90–95) per cent.

The material is claimed to exhibit high resistance to creep in the range 800°–1050°C.: it is intended for turbine components and other applications for which 'super alloys' are used.

C. G. GOETZEL, N. J. GRANT, J. A. YOBLIN and L. P. SKOLNICK, assignors to SINTERCAST CORPN. OF AMERICA. *Canad. Pat.* 559,409.

Forgeable Age-Hardenable Austenitic Steel for Superheater Tubing

The austenitic steels covered by the patent were developed to satisfy the following requirements: (1) an alloy content as low as is compatible with

C %	Si %	Cr %	Ni %	Mn %	Cu %	Mo %	Ta or Ta/Nb %	V %	N %
0·12	0·4-0·88	14·9-18	14-15·15	0·8-1·75	2·97-3	2·5-3	0·5-1·39	—	0·15-0·25
0·08-0·12	0·3-0·75	16·25-18	12-15	0·8-1·75	—	2-3	1-2	—	0·1-0·18
0·041-0·11	0·5-0·88	14·7-17	14-15	1·5-1·85	2·45-2·5	1·18-1·5	0·5-2·06	0·5-0·53	0·11-0·21

stress-rupture strength, at temperatures of the order of 1350°F. (732°C.), at least twice that of the 18-8 chromium-nickel steels; (2) corrosion-resistance and freedom from embrittlement under operating conditions; (3) forgeability and weldability; (4) satisfactory mechanical properties.

Steels meeting these conditions are of a basis composition falling within the following limits: carbon 0·02-0·15, chromium 14·7-20, nickel 12-18, manganese 0·25-2·5, silicon 0·1-1, per cent. The chromium content is sufficiently high to ensure adequate oxidation- and corrosion-resistance, but not so high as to cause sigma-phase formation: the nickel content is sufficient to maintain the steel in fully austenitic condition. Creep-rupture strength is achieved by alloying additions designed to render the steel age-hardenable: copper 2-3, molybdenum 1-3, tantalum or niobium/tantalum 0·5-2·06, nitrogen 0·1-0·25, per cent. The steel may also contain up to 1 per cent. of vanadium. Three preferred ranges of composition claimed are shown in the table above.

BABCOCK AND WILCOX CO. *Brit. Pat.* 800,225. Similar to *U.S. Pats.* 2,824,796; 2,824,797.

Production of Hollow Gas-Turbine Blades

Components which are to contain hollow passages or vents (e.g., gas-turbine blades) are produced by filling the hollows prepared in the rough work piece with cores of an iron-aluminium alloy possessing deformation characteristics similar to those of the component, forging the workpiece to the desired shape, and finally removing the cores from the hollows by means of an acid which does not attack the blading material. The cores may be inserted into the hollows as rods, or in molten or powder form. To dissolve the cores 25 per cent. hydrochloric acid solution is used (at 70°C.): this reagent does not react, for example, with the high-nickel turbine-blading alloys. Removal of the cores is claimed to be rapid and complete. The cores may be deformed during forging but will effectively retain the hollows in the workpiece.

BRIT. IRON AND STEEL RESEARCH ASSOCN. (inventor, F. E. EBORALL). *Brit. Pat.* 797,667.

Surface Treatment for Reduction of Intergranular Oxidation in High-Temperature Alloys

The patent covers surface treatment for prevention of the intergranular oxidation liable to occur at the surface of high-temperature alloys of nickel or cobalt base. Improved resistance to thermal shock, fatigue and creep is thus obtained. The component is heated (in a hydrogen or argon atmosphere), in contact with a powdered alloy containing at least 15 wt. per cent. of titanium and 6 wt. per cent. of aluminium (preferably ferro-titanium or nickel-titanium hardeners) for a period sufficiently long to achieve a modified surface layer of 0·0005-0·001 in. (0·0125-0·025 mm.) in depth. The treatment temperature should be the maximum above the normal working temperature of the material which is compatible with avoidance of any permanently adverse effects to its physical properties. The component, together with the powdered alloy, is packed in a heat-resisting box through which the inert gas is passed. Where the component consists of an age-hardenable alloy the box is heated to the solution-treatment temperature and the article may subsequently be aged at the temperature and for the time necessary to restore or achieve its full mechanical properties.

Features of the process specifically claimed for application to nickel-base alloys of the 'Nimonic' type involve heating in the range 1000°-1190°C. and ageing at 690°-710°C. for 12-16 hours. Suitable compositions of powdered alloy are given. The patent includes details of fatigue and thermal-shock tests on surface-treated 'Nimonic 90', illustrating the improvements achieved. Treated specimens are stated to have a life of 230 thermal cycles, *vis-à-vis* 105 cycles for untreated specimens.

BRISTOL AERO ENGINES, LTD. (inventors, G. LLEWELYN and R. G. UBANK). *Brit. Pat.* 797,855.

Protection of Molybdenum from Oxidation

An adherent oxidation-resisting coating, claimed to possess high resistance to impact, abrasion and thermal shock, is produced on molybdenum (or alloys containing molybdenum) by flame-spraying the basis metal with a powdered nickel-silicon-boron alloy of the following percentage composition: carbon 0·05-0·10, silicon 2·5-4·0, boron 1·5-2·2, remainder nickel. The sprayed component is heated to the fusing temperature of the coating (about 2100°F. : 1150°C.), causing the powdered alloy to melt and form a metallurgical bond with the basis metal. Prior to spraying, the surface should be electropolished and finally roughened (by grit-blasting). Both flame-spraying and heat-treatment should be carried out in a reducing atmosphere, and

where the component is of irregular shape it must be rotated during the fusing operation, to ensure an even coating. The particle size of the nickel-silicon-boron alloy should not exceed −200 mesh, and the final hardness of the coating should not be greater than 40 Rockwell C. A particular application of the process is the coating of gas-turbine blades.

GENERAL ELECTRIC CO. (inventor, M. A. LEVINSTEIN).
Brit. Pat. 798,624.

Nickel-base Brazing Alloys

The alloys referred to in the patent are claimed to be especially well adapted for use in exothermic gas atmospheres and for torch brazing, but slightly modified compositions may be used in reducing and neutral atmospheres. Limits of basis composition are: nickel 38–64·5, iron 25–54·5, phosphorus 8–14, per cent. Formation of brittle areas is prevented, without impairment of flow characteristics, by addition of one or more of the following (in individual amounts of from 2·5–10, and up to a combined total of 25, per cent.): copper, cobalt, chromium, manganese, molybdenum and tungsten. Up to 1·2 per cent. of lithium may be included to increase fluidity and wettability, and the alloy may also contain silicon and/or sulphur and/or carbon to a total limit of 5 per cent. Inclusion of chromium is preferred when brazing is to be carried out in argon or dry hydrogen, but is not recommended in alloys intended for use in exothermic gas atmospheres.

Temperatures for brazing in neutral or reducing atmospheres range from 1650°-2100°F. (900°-1150°C.), while the minimum temperature at which the alloys should be used in exothermic atmospheres is 1850°F. (1010°C.).

COAST METALS, INC. *Brit. Pat.* 797,800.

Nickel-Chromium-(Iron) Arc-Welding Electrodes

The core of the electrode consists of an alloy based on chromium, iron and nickel (which may be present, respectively, in percentages of 10–25, 0–20 and at least 50). The basic composition of the flux coating falls within the limits: calcium carbonate 30–50, cryolite 15–35, calcium silicate 5–15 per cent. In addition, the electrode contains molybdenum (0·5–7 wt. per cent.), niobium (1·5–5 wt. per cent.) and manganese (0·75–4 wt. per cent.), the inclusion of which is stated to reduce or eliminate the hot cracking to which a weld made from a core of nickel-chromium-iron is susceptible due to dilution with iron from the basis metal. Any one of the three elements may be present either wholly in the flux, wholly in the core or partly in both: the molybdenum is, however, preferably present in the coating. The flux coating may also contain up to 1 per cent. of lithium carbonate (which facilitates slag removal), up to 5 per cent. of bentonite (which facilitates extrusion of the coating), and 3–8 per cent. of chromium oxide (as a colorant for identification purposes). Since the presence of aluminium, which is frequently used as a deoxidizing agent for nickel-chromium alloys, can contribute to hot-cracking when the weld is produced under restraint, the aluminium content of the core must be $<0{\cdot}12$ per cent., preferably $\geq 0{\cdot}06$ per cent. Claims are made also for two electrodes of specified compositions.

MOND NICKEL CO., LTD. *Brit. Pat.* 798,153.
Similar to *U.S.* ,, 2,798,824.

Bonding of Aluminium to Stainless Steel

A light metal, such as aluminium or magnesium, is bonded to a second metallic material (e.g., a steel) by means of an intermediate bonding metal (preferably molybdenum, titanium, cobalt or nickel), which has a melting point above the boiling point of the light metal and above the melting point of the other metal. The intermediate metal is sprayed, at a temperature above its melting point, onto the light metal to vaporize a thin surface layer, thus providing an unoxidized surface upon which the bonding metal is deposited. The sprayed metal is the first to solidify, and some of the vaporized metal eventually condenses and freezes on the surface of this coating. Thereafter the second metal is sprayed onto the coating, and alloys with the unoxidized film of condensed metal, until, with continued spraying, a stage is reached when the remaining amount of second metal sprayed on is no longer alloyed and provides sufficient uncontaminated metal for finishing and machining.

The primary purpose of the invention is to provide a method of incorporating, in aluminium pistons used in internal-combustion engines, stainless-steel sections which would contain the grooves for the piston rings and be sufficiently hard to reduce groove wear caused by the rings at operating temperatures. This application of the process is described in detail.

J. J. DAILEY and J. E. FOX, assignors to JOHN ALTORFER.
U.S. Pat. 2,833,668.

Nickel-Aluminium Bronze Resistant to Stress-Corrosion

The aluminium bronzes of the invention were developed as a result of the discovery that intergranular corrosion of α aluminium bronze under conditions involving stress and exposure to steam can be substantially prevented by the addition of tin (0·05–1) per cent.) and/or silver (0·05–0·5 per cent.) to the alloy. (It is believed that the tin and silver, having a larger atomic size than aluminium, prevent the aluminium from migrating and forming the aluminium-rich grain boundaries which would be susceptible to corrosion.) The basis alloy contains aluminium 5–8, iron 0·2–4, nickel 0·01–5, per cent., copper balance. Preferred composition ranges are cited as suitable for specific components.

J. F. KLEMENT, assignor to AMPCO METAL INC.
U.S. Pat. 2,829,972.

Corrosion of 'Hastelloy B' by Phosphoric Acid: Inhibition by Addition of Cupric Ions

Corrosion of the nickel-molybdenum-base alloy 'Hastelloy B' by liquid phosphoric acid is inhibited, at acid concentrations of 70 per cent. and above, and at solution temperatures of at least 290°F. (143°C.), by maintenance, in the acid solution, of cupric ions in amounts ranging from 2 to 25 parts per million.

Such inhibitory measures will extend the possibility of using the alloy as a material of construction for plant employed for polymerization processes in which phosphoric acid is used as catalyst. The inhibition conferred by addition of the cupric ions would allow acid temperatures to be raised and acid concentrations to be lowered.

CALIFORNIA RESEARCH CORPN. *Brit. Pat.* 797,267.
Similar to *Australian* „ 212,527.

Nickel-Chromium-Molybdenum-Iron Alloys for Bleaching Apparatus

Chlorite solutions used for bleaching textiles are operated under conditions which are extremely corrosive to the constructional materials used for the bleaching equipment (e.g., pH 2·5–6; temperature 80°–90°C.).

The alloy which is the subject of this patent is claimed to be almost completely resistant to acid chlorite solutions, even at concentrations in excess of those normally used. It consists of carbon 0–1, silicon 0–1, nickel 40 min., chromium 10–28 (preferably 12–20), molybdenum 4·5 min. (preferably 15–20), iron 4·5 min. (preferably 4·5–10), tungsten 0–10, manganese 0–2, per cent. The combined iron and molybdenum contents should be less than that of the nickel.

DEUTSCHE GOLD- UND SILBER-SCHEIDEANSTALT. *Brit. Pat.* 796,619.

Attention is drawn to the fact that many of the names of materials mentioned in The Nickel Bulletin are *Registered Trade Marks*.

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A Private Exhibition

will be held by **THE MOND NICKEL COMPANY LIMITED**

at the

COLLEGE OF AERONAUTICS
CRANFIELD, BEDFORDSHIRE

on 18-21 NOVEMBER 1958

The exhibition will deal with the properties and applications of Nickel Alloys and Related Materials and will be of interest to
Engineers, Designers, Metallurgists and Students

IT WILL OPEN DAILY AT 10 A.M. FREE TICKETS AVAILABLE ON APPLICATION